A FEASIBILITY STUDY FOR A WOOD-FIRED STEAM ENGINE/GENERATOR SET FOR ELECTRICITY GENERATION AT FORT WARE, B.C.

86-05618/

A FEASIBILITY STUDY

FOR A WOOD-FIRED STEAM ENGINE/GENERATOR SET

FOR ELECTRICITY GENERATION

AT FORT WARE, B.C.

Prepared for:

Fort Ware Band Council
and
Indian and Northern Affairs Canada

Prepared by:

B.H. Levelton & Associates Ltd.
W.C. Edwards
Woodland Resource Services Ltd.
H.A. Olson

With contributions from:

Indian and Northern Affairs Canada
and
Remote Community Demonstration Program
of Energy, Mines and Resources Canada

November 1984

RCDP/PDCE-40

This report was prepared with contributions from Indian and Northern Affairs Canada and the Remote Community Demonstration Program of Energy, Mines and Resources Canada (EMR). Distribution of this report by EMR does not necessarily signify that the contents reflect the views and policies of either department. Mention of trade names and commercial products does not constitute recommendation or endorsement for use.

CONTENTS

		Page
SUMMARY		xi
RÉSUMÉ		xxiii
I.	INTRODUCTION	1
	A. Background	1
	B. Scope of Work	5
II.	LOCATION AND DESCRIPTION OF FORT WARE	7
	A. Location and Modes of Access	7
	B. Population	9
	C. Employment and Traditional Native Activities	10
	D. Layout of the Community	14
	E. Data for Climate and the Flow rate of the Finlay River	18
III.	THERMAL AND ELECTRICAL ENERGY REQUIREMENTS	22
	A. Description of Energy Uses in Fort Ware	22
	1. Thermal Energy Uses	22
	(a) Space Heating	22
	(b) Domestic Hot Water	22
	2. Electrical Energy Uses	23
	B. Thermal Energy Requirements	24
	1. Space Heating	24
	2. Domestic Hot Water	32
	C. Electrical Energy Requirements	36
IV.	DESIGN OF THE WOOD-FIRED POWER PLANT	48
	A. General Design Considerations	48
	B. Power Plant Capacity	49
	C. Delivery, Drying and Storage of Wood Fuel	54
	D. Siting and General Layout	55
	E. Selection of Plant Equipment	60
	1. Fuel Preparation and Handling	64
	2. Boiler	68
	3. Steam Engine and Generator	78
	(a) Performance Characteristics and Suppliers of Steam Engines	78
	(b) Selection and Sizing of the Engine	89
	4. Steam Turbine and Generator	94
	5. Connection to Power Distribution Network	96
	6. Waste Heat Removal and Recovery	98
	7. Systems for Supply of Makeup and Cooling Water	105
	(a) Water Supply	105
	(b) Makeup Water	108
	(c) Cooling Water	112
	8. Power Plant Building	113

		Page
IV.	DESIGN OF THE WOOD-FIRED POWER PLANT (continued)	
	F. Energy and Material Balance	114
	1. Power Output of Plant	114
	(a) Steam Engine Based Plant	114
	(b) Steam Turbine Based Plant	118
	2. Energy Balance	118
	3. Material Balance	120
	G. Plan for Plant Construction and Shipment of Supplies	123
	1. Equipment Shipment	123
	2. Considertions for Plant Construction	126
	H. Capital Costs	126
	I. Operating Costs	128
V.	WOOD FUEL HARVESTING AND MANAGEMENT	131
	A. Introduction	131
	B. The Resource	134
	1. Tenures	135
	(a) Timber Sales Licence	135
	(b) Forest Licence	135
	(c) Woodlot Licence	136
	2. Field Assessment	137
	C. The Sources of Energy	138
	1. Deciduous Volumes in Mature Stands	138
	2. Immature Deciduous Volumes	140
	D. The Harvesting and Management Plan	141
	1. The Design	141
	2. The Plan	142
	3. The Suggested Harvesting Plan	143
	4. Harvesting Constraints	143
	5. Equipment Available for Harvesting	144
	6. The Recommended Method of Development and Harvesting	144
	7. Training and Manpower	148
	(a) Training	148
	(b) Manpower	150
	8. Implementation Plan	151
	9. Equipment Operating Costs	152
	10. Unit Costs Delivered to the Plant Site	153
	E. Overheads	
	1. Supervision and Monitoring	154
	2. Projected Overhead Costs for the Project	155
VI.	ECONOMIC ANALYSIS	
	A. Steam Engine Based Plant	157
	B. Steam Turbine Based Plant	163
	C. Steam Engine Based Plant with Heat Recovery	163
	D. Diesel-Fired Power Plant	167

		Page
VII.	MANPOWER AND TRAINING REQUIREMENTS	172
	A. Manpower	
	1. Fuel Harvesting	172
	2. Plant Opertion	172
	B. Training Requirements	176
	1. Fuel Harvesting	177
	2. Plant Operation	177
VIII.	TENTATIVE PLAN AND SCHEDULE OF ACTIVITIES FOR IMPLEMENTING THE PROJECT	181
	A. Major Considerations	181
	B. The Plan and Schedule	182
	1. Phase 1	182
	2. Phase 2	184
	3. Phase 3	185
IX.	BENEFITS TO THE COMMUNITY OF A WOOD-FIRED POWER PLANT	187
X.	CONCLUSIONS AND RECOMMENDATIONS	189
	A. Conclusions	189
	B. Recommendations	197
REFERENCES		200
APPENDIX I	Abbreviated List of Equipment Suppliers	202
APPENDIX II	Performance Data for Steam Engines Manufactured by Skinner Engine Co. and Spillingwerks	206
APPENDIX III	Equipment and Road cost	214
APPENDIX IV	Unit Costs Delivered to the Plant Site	216
APPENDIX V	Explanation of Type Coding and Species Abbreviations	218

LIST OF TABLES

TABLE NO.			Page
II-1	-	Climatic Data for the Ware Station From Environment Canada	19
II-2	-	Annual Extremes of Discharge for the Period of Record, Finlay River at Ware	20
II-3	-	Summary of Spot Measurements of Water Temperature for the Period of Record - Finlay River at Ware	21
III-1	-	Furnaces Installed	26
III-2	-	Buildings Maintained by Indian and Northern Affairs	27
III-3	-	Annual Thermal Energy Consumption of the Indian and Northern Affairs Facilities	29
III-4	-	Estimated Heat Load for the Proposed Community Building	31
III-5	-	Installed Domestic Hot Water Tanks	34
III-6	-	Maximum Hourly and Average Daily Hot Water Use and Heat Load for the School and Community Centre	35
III-7	-	Inventory of Diesel Electric Generator Sets In Place at Fort Ware	37
III-8	-	Connected Load for the Wtaer Supply System and Washhouses	41
III-9	-	Peak Electrical Power Demand for Fort Ware	44
IV-1	-	Analysis of Water from the Two Deep Community Water Wells at Fort Ware	109
IV-2	-	Summary of Capital Costs for the Base Case Plant	127
IV-3	-	Summary of Operating Costs for the Base Case Plant	129

LIST OF TABLES (Continued)

TABLE NO.			Page
V-1	-	Estimated deciduous volume by source	140
V-2	-	Annual Fuel and Lubricating Oil Requirements	152
V-3	-	Project Overhead Costs	156
VI-1	-	Economic Assumptions and Definitions	158
VI-2	-	Annual Costs, Power Production and Power Cost for a 175 kW Steam Engine Based Power Plant	160
VI-3	-	Summary of Calculated Powr Prices for the Steam Engine Based Plant	161
VI-4	-	Annual Costs, Power Production and Power Cost for a 175 kW Steam Engine Based Plant with Heat Recovery	165
VI-5	-	Summary of Calculated Power Prices for a Steam Engine Based Plant with Heat Recovery	166
VI-6	-	Annual Costs, Power Production and Power Cost for a 150 kW Diesel-Fired Power Plant	170
VI-7	-	Summary of Calculated Power Prices for the Diesel-Fired Plant	171

LIST OF FIGURES

FIGURE NO.	TITLE	Page
II-1	- Location Map for Fort Ware	8
II-2	- Population Distribution for Fort Ware as of December 31, 1982	11
II-3	- Layout of Existing and Committed Buildings at Fort Ware	15
II-4	- Tentative Plan for Future Roadways and Location of Proposed Power Lines	17
III-1	- Heat Load by Month for Facilities of Indian and Northern Affairs	30
IV-1	- The Preferred Site for the Power Plant	56
IV-2	- Photograph Taken Looking South Along the Kwadacha Trail Towards the School	58
IV-3	- General Plant Layout	59
IV-4	- Schematic Diagram of the Base Case Power Plant	61
IV-5	- Schematic Diagram of the Power Plant Configured for Recovery of 1.4 GJ/L from the Cooling Water for Heating Applications	63
IV-6	- Typical Arrangement of a Firetube Boiler for Wood Chips	71
IV-7	- Comparison of Steam Travel in Cylinders of Counterflow and Uniflow Engines	79
IV-8	- Cross-Section of a Vertical Universal Unaflow Steam Engine Manufactured by Skinner Engine Co.	85
IV-9	- Cross-Section of a Two-Cylinder Spillingwerk Steam Engine	87
IV-10	- Simplified Schematic of Power Distribution Within the Plant and to the Power Lines	97

LIST OF FIGURES (Continued)

FIGURE NO.	TITLE	Page
IV-11	- Cooling Water System for the Power Plant at 175 kW Output Without Heat Recovery	99
IV-12	- Cooling Water System for the Power Plant at 175 kW Output With Heat Recovery	102
IV-13	- Energy Balance for the Power Plant at 175 kW Output	119
IV-14	- Material Balance for the Power Plant at 175 kW Output	121
V-1	- The Resource Sites	139
V-2	- An Example of a Typical Cutting Area	146

SUMMARY

A. Introduction

The overall objective of this study was to assess the technoeconomic feasibility of a wood-fired steam power plant for supplying electricity in Fort Ware. Included in the study are estimates of electricity and heat requirements, a wood harvesting and forest management plan, designs of wood-fired power plants using a steam turbine and steam engine and an economic analyses of wood-fired plant options and a comparably sized diesel-fired plant. A steam engine was the main prime mover considered because of its robust construction, minimal requirement for maintenance, long service life and relative simplicity.

Fort Ware is a Reserve having a population of some 170 people which lies 440 km north northwest of Prince George on the north bank of the Finlay River. It is a remote community accessible by air year-round and by water when the waterways are ice-free and not blocked by floating debris. The community consists of some forty residences, a school and associated teachers' residences, a store, a church, a post office, a nursing clinic and miscellaneous other buildings.

B. Energy Requirements

Thermal energy is used in Fort Ware for space heating and domestic hot water. Buildings maintained by Indian and Northern Affairs (I & NA) and Health and Welfare Canada utilize diesel fuel for space heating and supplying domestic hot water. All other heated buildings in the community including native residences utilize wood for fuel.

Electricity is used in the school, teachers' residences, nursing clinic, store, Band office, church, Band storage shed and, temporarily, in two residences near one of the installed generator sets. Except for the residences mentioned above, none of the other residences in the community has access to electric power. Three diesel-fired generator systems are in place at Fort Ware, one being operated by the Band to supply a few community buildings (10 and 14 kW units), one being operated to supply the nursing clinic (two 12 kW unit) and the final and largest system being operated by I & NA to supply the school, teachers' residences and the domestic water supply and wash houses (three 44 kW units).

The peak electricity demand of the community over the long term, after allowance for diversity and including the requirements of a proposed community centre, was determined to be 176 kW. The annual power consumption of the community was estimated at 455,000 kWh.

Thermal loads which are candidates for supply using waste heat from a wood-fired power plant are the space heating and hot water loads of the school and the proposed community centre. The total peak thermal demand estimate for these buildings is 1.4 GJ/h. The average annual thermal energy consumption was estimated to be 1247 GJ for space heating and 128 GJ for domestic hot water.

C. Design of Wood-Fired Power Plant

A wood-fired power plant having a continuous rated output of 175 kW was chosen for analysis. A plant of this capacity appears to have the best fit to the design requirements:

- it would be able to satisfy the immediate electrical requirements of the community and the plant itself;
- it requires a wood supply that can be readily supplied from the surrounding forest using a minimum of mechanical equipment;
- it incorporates a boiler that, according to the Provincial Pressure Vessel Act, requires only one 4th Class power engineer to act as Chief Engineer, and three boiler operators as shift engineers.

The plant design with a steam engine has a net output to the community at rated conditions of 140 kW, the balance being consumed by the plant itself. The total annual power consumption of the community and the power plant equipment is 643,000 kWh.

Initially, a wood-fired power plant could satisfy all the electrical requirements of the community. In four to five years, as power demand increases, the total power demand may exceed the output capacity of the plant. Power demand in excess of the capacity of a wood-fired plant could be effectively satisfied by synchronously generating additional power with the existing diesel-fired power system operated by I & NA. This approach allows the wood-fired plant to operate as a base-load unit, and the diesel-fired plant to operate as a peak-load unit, which is consistent with the strengths of each type of equipment.

The base case wood-fired power plant consists of a storage area for cordwood, a chipper to produce the boiler fuel, a bin and conveying equipment, a fire-tube boiler designed with a working pressure of 1720 kPa and output of 0.7 kg/s, a steam engine/generator and air pollution control equipment. The boiler plant will operate under automatic control and requires operators for supervision and to take care of routine maintenance. Electricity is generated at 600V, 3 Ø, and is stepped up to 2400/4160V Wye for distribution to the community through overhead lines. Cooling water is needed to condense the exhaust steam from the steam engine for return to the boiler. This water is obtained from a well near the plant.

An alternate plant design was considered which utilized a steam turbine instead of a steam engine. All other parts of the plant were the same as in the base case design.

One other option that was considered allowed for recovery of waste heat from the base case plant to satisfy the thermal load of the school and community centre.

The wood-fired plant utilizes Aspen, Cottonwood and Birch harvested from Crown Forest in mature and immature stands of softwoods and hardwoods. The trees are cut and split in the woods to a size 1.2 m in length and 20 cm in maximum diameter and transported to a storage and drying area adjacent to the power plant. This fuel wood dries naturally to a moisture content of 20%, wet basis.

The annual fuel consumption of the plant, baed on a total power use of 643,000 kWh, is 1700 OD tonnes (1700 cords). This amount of fuel could be readily supplied from the surrounding Crown Forest within an 8 km radius of Fort Ware.

The base case plant converts 8.2% of the heating value of the fuel into electrical energy. The net efficiency of the plant, which allows for power consumed by the plant itself, is 6.6%. The overall efficiency of the base case power plant with heat recovery is 26.3% based on gross energy output.

The overall efficiency of the power plant with a steam turbine is 6.6%. In this case, the output of the plant is limited to 140 kW (gross) because the steam turbine has a lower efficiency than the steam engine under the steam conditions used.

D. Wood Fuel Harvesting and Management

The plan for the harvesting and management of the wood for the plant took into consideration the requirements of plant equipment, the abilities of Band members, training requirements, employment generated and costs.

A cursory examination of the resource present in the Crown Forest surrounding Fort Ware by the Ministry of Forests indicated that there is more than enough deciduous volumes for a wood-fired power plant. Application may be made to the Ministry for a Timber Sale licence, Forest Licence or Woodlot Licence to utilize the available resource. The most attractive form of tenure for the Band is the Timber Sale Licence, which is the least onerous of all tenures.

The recommended fuel harvesting program involves:

- harvesting from the Kwadacha West area initially, moving to the Kwadacha East and Finlay areas once hardwoods in the Kwadacha West are exhausted;

- utilizing skid trails to gain access to the forest and seven to eight cutters to fall trees and cut and split them to the required size;

- transport of the cordwood using two to four porters, two tractors and two wagons from the woods to the plant site.

Much of this recommended harvesting method will entail handwork. Addition of a loader to increase productivity could be considered once the harvesting crew has gained experience and there is justification for this increased mechanization.

Under the labour intensive plan recommended for initial implementation, the unit cost of cordwood delivered to the plant is $56.21/OD tonne. Introduction of a loader results in a reduction of this cost to $47.61/OD tonne. Overhead costs are additional to the above unit costs and vary depending on the quality of fuel harvested. At the estimated power consumption level, 1700 OD tonnes of wood are needed. The overhead costs in this case amount to $20.53/OD tonne in the first-year and $4.88/OD tonne in all subsequent years. Of course, the power consumption will increase from a base level in the first year of operation to the design value after a few years of operation, and the overhead costs must be adjusted accordingly.

E. Economic Analyses

Economic analyses were done for four plant designs using cost esimates made in this study. Three wood-fired plants were considered: a steam engine plant; a steam turbine plant; and a steam engine plant with heat recovery. For comparison purposes a diesel-fired plant was investigated which had a net power output similar to the steam engine based plant.

For all cases, the uniform power cost in 1984 dollars which yielded equality between present values of costs and revenues over the life of the plant was determined. Some of the more important results are summarized below using gross plant output to determine power cost:

DESIGN	SCENARIO	POWER COST (1984 Dollars/kWh)
Steam Engine	Base case	0.579
	- use a loader in and after the 2nd year - labour cost reduced 15% - capital cost reduced 10%	0.516
Steam Turbine Based Plant	Base case	0.659
Steam Engine Based Plant With Heat Recovery	Base Case	0.533
	- use a loader in and after the 2nd year - labour cost reduced 15% - capital cost reduced 10% - heat load increased to 2750 GJ by 1995	0.430
Diesel-Fired Plant	Base Case	0.426

The calculated power costs are based on gross output not net output. Much more power is required by a wood-fired power plant than a diesel-fired power plant, and, therefore, care must be

exercised when referring to the power costs tabulated above. The least cost scenario tabulated above for a wood-fired power plant yields a power cost of $0.608 kWh on the basis of power delivered to the community.

F. Conclusions and Recommendations

1. A wood-fired power plant having a continuous rated output of 175 kW is best suited to Fort Ware for reasons of scale of the fuel harvesting operation and the lesser requirements for training boiler operators. To achieve this power output while keeping the size of the boiler and the wood requirements of the plant within practical limits, a steam engine must be used as the prime mover for the generator.

   The boiler for this size of plant has a heating surface area of less than 100 m^2 and, therefore, could be operated under the control of a chief engineer having a Fourth Class certificate and three shift engineers having boiler operators certificates.

   The net power output of a steam engine based plant is 140-145 kW, less than the 175 kW rated output because of the power consumed by the plant itself. The net output is less than the estimated peak demand of the community (176 kW). Enlarging the size of the plant to satisfy the peak demand of the community is not attractive because this would necessitate use of one Third Class and three Fourth Class operating engineers, as well as an enlarged harvesting operation.

When the peak demand for power reaches the maximum capacity of the wood-fired plant, perhaps after four to five years of operation, the preferred means for satisfying the shortfall is by synchronously generating power using the existing diesel-fired power plant. This allows both plants to operate under conditions which best suit their respective operating characteristics.

2. A steam engine is preferable to a steam turbine as the prime mover for the plant because of its higher efficiency (lower steam requirement per unit of power output) at the steam conditions practical for the plant.

3. The most suitable location for a wood-fired power plant is north of the school complex on unoccupied land near the start of the Kwadacha trail. This site is on the eastern edge of the area selected for future community expansion and, therefore, would minimize the impact of the plant on residents. Wood would be delivered to the plant initially along the Kwadacha trail, which is away from dwellings and the school, thereby reducing safety hazards, and dust and noise nuisances. The plant site is close enough to the school and proposed community centre to justify piping of hot water to these locations for recovery of waste heat.

   The plant would occupy 0.77 ha of land in total.

4. The Crown Forests within an 8 km radius of Fort Ware are capable of supplying sufficient hardwoods for the plant for well in excess of 25 years of operation. The most suitable form of tenure by which the Band could utilize the wood resource is a Timber Sale Licence.

5. A labour intensive wood harvesting plan could be used by the Band to cut, split and deliver fuel for the plant. The plant developed in this study is compatible with the abilities of Band members and requies a minimum of mechanical equipment that would have to be operated and maintained. A one-year supply of fuel is kept at the plant to give time for air drying and prevent interruptions in fuel supply that might otherwise arise because of delays in the fuel harvesting operation.

6. Recruiting and training Band members to operate the power plant on a continuous basis is the part of the project most subject to failure. Recruiting and training Band members for the fuel harvesting operation is an achievable objective. Operators of the power plant must pass correspondence courses, obtain work experience and pass the Provincial examinations before being certified. With the support of the Band and involvement of the I & NA school teachers to assist Band members with their coursework, it is expected that a complete crew for the boiler plant could be trained. The training period for the boiler operators could extend beyond the eight and twelve months normally expected for boiler operators and Fourth Class Engineers, respectively.

7. Considering only the cost of producing electricity to serve the community, the most economical route is the use of a diesel-fired power plant. This approach would involve some local labour to supervise the engines and ensure they are properly maintained, but, at most, only one person, half time would be required. A diesel plant would be a major source of noise in the community.

8. Considering the need for employment, development of trade skills and reduction of oil consumption in Fort Ware, as well as the objective of minimizing the cost of producing power, use of a wood-fired power plant having a gross output of 175 kW and complete with a system for recovery of waste heat is recommended. Recovered heat should be used to supply the school and the proposed community centre.

9. Because of the potential for difficulties with recruiting, training and maintaining a work force for the fuel harvesting and plant operation tasks, Phase 1 of the project should be implemented first, preferably beginning in April 1985 or sooner, weather permitting. Phase 1, which could be completed in about three months, consists of a forest inventory, survey and clearing of a main haul road to the Kwadacha West area, and evaluation of results. A Forester/ Forest Technician and a superintendent from outside the community would be needed for Phase 1. Band members would assist the Forester and conduct the road surveying and clearing work. The trees felled would be cut and split to size, then delivered to the plant storage area. Harvesting of this timber should proceed using the described labour intensive program.

An appraisal of progress and performance of the work program should be made in Phase 1 to otain information needed to assess whether implementation of Phase 2 of the project is feasible. The main concern is whether or not a reliable and functional work crew can be organized from the Band members for a long-term project. A further objective of Phase 1 of

the work is to give the Band an opportunity to become familiar with the total project and its impact on the community, and contribute comments with regard to personnel requirements, project management and system design.

The approximate cost of Phase 1 of the project may be itemized as follows:

Consultant Forester	$14,000
Superintendent	6,000
Survey Assistants	1,500
Supervisor elect	2,000
Wood harvesting 500 OD tonnes @ $56.21/OD tonne	28,000
Consultant for Assessment and re-evaluation	15,000
Contingency	10,000
	$76,500

ÉTUDE DE FAISABILITÉ D'UNE MACHINE À VAPEUR ALIMENTÉE AU BOIS ET D'UNE GÉNÉRATRICE POUR LA PRODUCTION D'ÉLECTRICITÉ À FORT WARE (COLOMBIE-BRITANNIQUE)

Résumé

A. Introduction

La présente étude a pour objectif global d'évaluer la faisabilité technique et la rentabilité d'une centrale thermique alimentée au bois servant à produire de l'électricité à Fort Ware. Elle comprend des estimations des besoins en électricité et en chaleur, un plan de récolte de bois et de gestion forestière, l'étude technique de centrales alimentées au bois utilisant une turbine à vapeur et une machine à vapeur, ainsi qu'une analyse économique des options de centrale alimentée au bois et d'une centrale au diesel de capacité semblable. La machine à vapeur est le principal moteur considéré à cause de sa robustesse, du peu d'entretien qu'elle exige, de sa longue durée de vie utile et de sa simplicité relative.

Fort Ware, dont la population est d'environ 170 habitants, est une réserve située à 400 km au nord-nord-ouest de Prince George sur la rive nord de la rivière Finlay. Cette collectivité éloignée est accessible par air toute l'année et par eau lorsque les voies navigables sont libres de glace et ne sont pas obstruées par des débris flottants. La collectivité se compose de quelque 40 résidences, d'une école et des résidences des enseignants, d'un magasin, d'une église, d'un bureau de poste, d'une clinique de soins infirmiers et de divers autres bâtiments.

B. Besoins en énergie

L'énergie thermique est utilisée à Fort Ware pour le chauffage des locaux et de l'eau sanitaire. Dans les bâtiments utilisés par Affaires indiennes et du Nord Canada (AINC) et par Santé et Bien-être social Canada le combustible diesel sert au chauffage des locaux et de l'eau chaude sanitaire. Tous les autres bâtiments de la collectivité, y compris les résidences des autochtones, sont chauffés au bois.

L'électricité est fournie à l'école, aux résidences des enseignants, à la clinique de soins infirmiers, au magasin, au bureau de la Bande, à l'église, à l'entrepôt de la Bande et provisoirement à deux résidences situées à proximité d'une des génératrices. Sauf les deux résidences susmentionnées, aucune des autres résidences de la collectivité n'a accès à l'électricité. Trois systèmes électrogènes alimentés au diesel sont en place à Fort Ware; la Bande en exploite un pour fournir de l'électricité à quelques bâtiments communautaires (groupes de 10 kW et 14 kW), un autre est exploité pour alimenter la clinique de soins infirmiers (deux groupes de 12 kW) et le troisième est exploité par AINC pour alimenter l'école, les résidences des enseignants,le réseau d'alimentation en eau et les buanderies (trois groupes de 44 kW).

Il a été déterminé que la demande d'électricité de pointe de la collectivité à long terme, compte tenu de la diversité et des besoins d'un centre communautaire proposé, est de 176 kW. La consommation annuelle de la collectivité est évaluée à 455 000 kW.h.

Les charges thermiques susceptibles d'être approvisionnées par les rejets thermiques d'une centrale alimentée au bois sont le chauffage des locaux et le chauffage de l'eau sanitaire de l'école et du centre communautaire proposé. La demande thermique de pointe totale de ces deux bâtiments est évaluée à 1,4 GJ/h. La consommation d'énergie thermique moyenne par an est évaluée à 1247 GJ pour le chauffage des locaux et à 128 GJ pour le chauffage de l'eau sanitaire.

C. Étude technique de la centrale alimentée au bois

Une centrale alimentée au bois ayant une puissance nominale de 175 kW a été retenue aux fins de l'analyse. Une centrale de cette puissance semble s'adapter le mieux aux exigences:

- elle pourrait satisfaire aux besoins immédiats en électricité de la collectivité et de la centrale elle-même;

- elle exige un approvisionnement en bois facile à récolter dans les forêts environnantes en ayant recours à très peu de matériel mécanique;

- elle comprend une chaudière dont la Pressure Vessel Act de la province permet l'exploitation par un seul mécanicien de machine fixe de 4^{e} catégorie comme mécanicien chef et trois conducteurs de chaudière.

La puissance nominale nette de la centrale examinée est de 140 kW, car la centrale elle-même consomme 35 kW. La consommation d'électricité annuelle globale de la collectivité et du matériel de la centrale s'élève à 643 000 kW.h.

Au début, une centrale alimentée au bois pourra satisfaire à tous les besoins en électricité de la collectivité. Dans quatre à cinq ans, cependant, avec la croissance de la demande d'électricité, la demande totale pourrait dépasser la puissance de la centrale. Il serait alors possible de satisfaire à la demande excédentaire par l'exploitation synchrone du système existant de production d'électricité alimenté au diesel exploité par AINC. Selon cette formule la centrale alimentée au bois serait exploitée pour la charge de base et la centrale alimentée au diesel pour satisfaire à la charge de pointe, solution qui correspond aux points forts de chaque type d'équipement.

L'option de base de la centrale alimentée au bois comporte: une aire d'entreposage pour le bois, une déchiqueteuse pour produire le combustible destiné à la chaudière, une trémie et le matériel de

transport, une chaudière ignitubulaire avec une pression de service de 1720 kPa et un débit de 0,7 kg/s, une machine à vapeur et une génératrice, et le matériel nécessaire de lutte contre la pollution atmosphérique. L'exploitation de la chaudière serait commandée automatiquement et demanderait la présence de personnel de surveillance et d'entretien courant. On produirait de l'électricité à 600 V, 3 Ø, et utiliserait un transformateur élévateur 2400/4160 V branché en étoile et des lignes aériennes serviraient pour la distribution de l'électricité à la collectivité. Un puits proche de la centrale fournirait l'eau de refroidissement requise pour condenser la vapeur de la machine à vapeur avant de la retourner à la chaudière.

Une deuxième option qui a été examinée, utilise une turbine à vapeur au lieu d'une machine à vapeur. Tous les autres éléments de la centrale seraient les mêmes.

La troisième option de centrale au bois examinée permettrait la récupération des rejets thermiques de la centrale afin de satisfaire à la charge thermique de l'école et du centre communautaire.

La centrale alimentée au bois brûlerait du tremble, du liard et du bouleau récoltés dans des peuplements d'arbres adultes d'essences résineuses et d'essences feuillues de forêts de la Couronne. Les arbres sont coupés et fendus dans la forêt en tronçons d'une longueur de 1,2 m et d'un diamètre maximal de 20 cm et transportés jusqu'à une aire de stockage et de séchage proche de la centrale électrique. Le combustible-bois sèche naturellement jusqu'à une teneur en eau de 20 % (base humide).

La consommation annuelle de combustible de la centrale, calculée en fonction de 643 000 kW.h, s'élève à 1 700 tonnes anhydres (1 700 cordes). Ce volume de combustible-bois serait facile à récolter dans la forêt de la Couronne dans un rayon de 8 km de Fort Ware.

La centrale de l'option de base convertit 8,2 % de la valeur thermique du combustible en énergie électrique. Le rendement net de la centrale, compte tenu de l'électricité consommée par la centrale elle-même, est égal à 6,6 %. Le rendement global de la centrale électrique de l'option de base, compte tenu de la récupération de chaleur, s'élève à 26,3 % selon la production brute d'énergie.

Dans le cas de la centrale munie d'une turbine à vapeur, le rendement global est égal à 6,6 %. Dans ce cas, la puissance brute de la centrale ne dépasse pas 140 kW, puisque le rendement de la turbine à vapeur est moindre que celle de la machine à vapeur dans les conditions de vapeur retenues.

D. Récolte et gestion du combustible-bois

Le plan établi pour la récolte et la gestion du bois destiné à la centrale tient compte des besoins en matériel, des capacités des membres de la Bande, des besoins en formation, de l'emploi créé et des frais.

Un examen sommaire des ressources disponibles dans la forêt de la Couronne aux alentours de Fort Ware par le ministère chargé des Forêts indique que la forêt contient plus que le volume nécessaire d'essences feuillues pour alimenter la centrale envisagée. On peut demander au ministère les permis nécessaires (Timber Sale Licence, Forest Licence ou Woodlot Licence) pour exploiter les ressources disponibles. Dans le cas de la Bande, la formule la plus intéressante serait celle du Timber Sale Licence; la moins coûteuse des options disponibles.

Le programme de récolte recommandé comporte:

- en premier lieu, coupe dans la région de Kwadacha ouest, et une fois que les feuillus y sont épuisés, des coupes dans les régions de Kwadacha est et Finlay;

- l'emploi de sentiers de halage pour pénétrer dans la forêt et d'équipes de six à huit bûcherons pour abattre les arbres, les tronçonner et les fendre aux dimensions voulues;

- transport du bois coupé à l'aide de quatre porteurs, deux tracteurs et deux wagons de la forêt jusqu'à la centrale.

La méthode de récolte recommandée comporte beaucoup de travail manuel. Il conviendrait de considérer l'acquisition d'un chargeur pour accroître la productivité une fois que l'équipe de récolte a accumulé de l'expérience et que la mécanisation accrue est justifiée.

Le plan initial à fort coefficient de main-d'oeuvre donne un coût unitaire de bois livré à la centrale de 56,21 $ la tonne anhydre. L'adoption d'un chargeur ramène ces frais à 47,61 $ la tonne anhydre. Les frais généraux sont en sus des frais unitaires susmentionnés et dépendent de la qualité du combustible-bois obtenu. Étant donné le niveau de consommation d'électricité estimé, il faut 1 700 tonnes anhydres de bois. Les frais généraux dans ce cas s'élèvent à 20,53 $ par tonne anhydre la première année et à 4,88 $ par tonne anhydre dans les années subséquentes. La consommation d'énergie augmentera nécessairement après la première année d'exploitation jusqu'à la valeur nominale dans quelques années et il faudra rajuster les frais généraux en conséquence.

E. Analyses économiques

Des analyses économiques sont offertes pour les quatre centrales examinées à l'aide d'estimations des coûts. Trois centrales alimentées au bois sont examinées: une centrale avec machine à vapeur; une centrale avec turbine à vapeur; et une centrale avec machine à vapeur et matériel de récupération de chaleur. Aux fins d'une comparaison, on examine aussi une centrale alimentée au diesel d'une puissance nette semblable à celle de la centrale munie d'une machine à vapeur.

Dans tous les cas, on a déterminé le coût unitaire de l'électricité en dollars de 1984 associé à l'égalité entre la valeur actuelle des frais et des revenus sur la durée utile de la centrale. Le tableau ci-après résume une partie des résultats les plus importants, le coût de l'électricité étant déterminé par la capacité brute de la centrale.

MATÉRIEL	SCÉNARIO	COÛT DE L'ÉLECTRICITÉ (En dollars de 1984/kW.h)
Machine à vapeur	Option de base - chargeur pendant et après la deuxième année - frais de main-d'oeuvre moins 15 % - coût en capital moins 10 %	0.579 0.516
Turbine à vapeur	Option de base	0.659
Machine à vapeur et récupération de chaleur	Option de base - chargeur pendant et après la deuxième année - frais de main-d'oeuvre moins 15 % - accroissement de la charge thermique à 2 750 GJ avant 1995	0.533 0.430
Centrale alimentée au diesel	Option de base	0.426

Les coûts de l'énergie sont fondés sur la production brute et non sur la production nette. L'exploitation d'une centrale alimentée au bois consomme beaucoup plus d'électricité qu'une centrale alimentée au diesel, et il faut donc interpréter le tableau ci-dessus avec soin. En fonction de l'électricité fournie à la collectivité le scénario au coût le moins élevé pour une centrale alimentée au bois donne un coût d'électricité égal à 0,608 $/kW.h.

F. Conclusions et recommandations

1. Une centrale électrique d'une puissance nominale de 175 kW alimentée au bois convient le mieux à Fort Ware en raison de l'envergure des travaux de récolte de combustible et des besoins moindres en matière de formation de conducteurs de la chaudière. Afin d'obtenir cette puissance, tout en gardant dans les limites pratiques les dimensions de la chaudière et les besoins en bois, il faut utiliser une machine à vapeur pour entraîner la génératrice.

La chaudière exigée par une centrale de cette puissance a une superficie de chauffer inférieure à 100 m^2 et son exploitation est donc possible sous la surveillance d'un mécanicien en chef de machine fixe détenteur d'un certificat de quatrième catégorie et par trois mécaniciens munis de certificate de conducteur de chaudière.

La puissance nette d'une centrale munie d'une machine à vapeur est égale à 140-145 kW, donc inférieure à la puissance nominale de 175 kW, puisque la centrale elle-même consomme de l'électricité. La puissance nette est inférieure à la demande de pointe estimée de la collectivité (176 kW). Il n'est pas souhaitable d'accroître la puissance de la centrale afin d'être en mesure de satisfaire à la demande de pointe de la collectivité parce qu'il faudrait alors embaucher un mécanicien de machine fixe détenteur de certificats de quatrième catégorie et il faudrait aussi accroître les travaux de récolte de bois.

Après quatre ou cinq ans d'exploitation, lorsque la demande de pointe atteint la puissance maximale de la centrale alimentée au bois, le meilleur moyen de satisfaire à la demande excédentaire serait la production synchrone d'électricité à l'aide de l'installation existante alimentée au diesel. Les deux installations seraient ainsi exploitées dans les conditions qui conviennent le mieux à leurs caractéristiques d'exploitation.

2. La machine à vapeur convient mieux que la turbine à vapeur pour entraîner les génératrices parce que la machine à vapeur a un rendement plus élevé (exige moins de vapeur par unité de production) aux conditions envisagées.

3. Le meilleur emplacement pour une centrale alimentée au bois se trouve au nord des bâtiments de l'école dans les terrains inoccupés près du début du sentier Kwadacha. L'emplacement se trouve à la limite orientale du secteur retenu pour l'agrandissement futur de la collectivité et l'implantation de la centrale aurait ainsi le moins d'incidences possibles sur les résidents. Au début, on pourrait livrer le bois à la centrale le long du sentier Kwadacha, qui se trouve à une certaine distance des habitations et de l'école, ce qui permettrait de réduire les risques pour la sécurité et les effets nuisibles de la poussière et du bruit. Le site est cependant suffisamment proche de l'école et du centre communautaire proposé pour justifier le transport d'eau chaude par des conduites à ces bâtiments aux fins de la récupération des rejets thermiques.

   La centrale occuperait au total 0,77 ha de terrain.

4. Les forêts de la Couronne situées dans un rayon de 8 km de Fort Ware peuvent fournir suffisamment de bois dur pour alimenter la centrale pendant plus de 25 ans d'exploitation. La meilleure formule offerte à la Bande pour l'utilisation de la ressource forestière est celle du Timber Sale Licence.

5. La Bande pourrait opter pour un programme de récolte de bois à coefficient élevé de main-d'oeuvre. Le plan d'abattage, de tronçonnage, de fente et de livraison de combustible-bois à la centrale, proposé dans la présente étude correspond aux capacités des membres de la Bande et exige le moins de matériel mécanique possible à exploiter et à entretenir. Il est prévu de garder à la centrale un approvisionnement suffisant pour un an afin de permettre au bois de sécher à l'air et d'éviter toute interruption de l'approvisionnement en combustible à cause d'un retard dans les travaux de récolte de bois.

6. L'élément du projet le plus difficile à garantir est le recrutement et la formation des membres de la Bande pour l'exploitation permanente de la centrale électrique. Le recrutement et la formation des membres de la Bande pour les travaux de récolte de bois constituent un objectif réalisable. Les exploitants de la centrale électrique doivent suivre des cours par correspondance, obtenir une expérience pratique et réussir les examens provinciaux afin d'obtenir les certificats nécessaires. Avec le soutien de la Bande et la participation des enseignants de l'école d'AINC pour aider les membres de la Bande avec les travaux liés au cours, il devrait être possible de former une équipe complète d'exploitation des chaudières. La période de formation des conducteurs de chaudière pourrait se prolonger au-delà des huit et douze mois prévus habituellement pour les conducteurs de chaudière et les mécaniciens de machine fixe de quatrième catégorie.

7. Si l'on tient compte uniquement du coût de production de l'électricité pour desservir la collectivité, une centrale alimentée au diesel est la solution la plus économique. Cette option comporte une certaine participation de la main-d'oeuvre locale pour surveiller les moteurs diesel et assurer leur entretien, mais il suffirait d'une seule personne à mi-temps pour l'exploitation. Une centrale alimentée au diesel constituerait en outre une grande source de bruit dans la collectivité.

8. Compte tenu du besoin d'emplois, de formation professionnelle et de réduction de la consommation de pétrole à Fort Ware, ainsi que de l'objectif de réduire le plus possible le coût de production de l'électricité, le choix d'une centrale électrique alimentée au bois ayant une puissance brute de 175 kW, munie du matériel de récupération des rejets thermiques, est recommandé. La chaleur récupérée pourrait servir au chauffage de l'école et du centre communautaire proposé.

9. Étant donné les difficultés éventuelles de recrutement, de formation et de maintien de la main-d'oeuvre pour la récolte de bois et l'exploitation de la centrale, il conviendrait de mettre en oeuvre d'abord la phase 1 du projet, préférablement au début d'avril 1985 ou avant, si les conditions météorologiques le permettent. La phase 1, qui demanderait environ trois mois à réaliser, comporte un inventaire

forestier, un levé et le défrichement du chemin principal conduisant au secteur de Kwadacha ouest et l'évaluation des résultats. Il faudrait pour cette phase un forestier et un technicien des forêts et un surveillant provenant de l'extérieur de la collectivité. Les membres de la Bande aideraient le forestier et exécuteraient le levé et les travaux de défrichement du chemin. Les arbres abattus seraient tronçonnés et fendus aux dimensions voulues et livrés à l'aire de stockage. La récolte du bois devrait se faire selon le programme à fort coefficient de main-d'oeuvre.

Une évaluation des progrès et de la réalisation du programme des travaux ferait partie de la phase 1 afin de fournir les renseignements nécessaires pour évaluer si la mise en oeuvre de la phase 2 du projet est faisable. Le point principal à résoudre est de savoir s'il est possible d'organiser une équipe de travail pour un projet à long terme avec des membres de la Bande. Un autre objectif de la première phase des travaux est de donner à la Bande la possibilité de se familiariser avec le projet global et les effets qu'il entraînerait pour la collectivité, de faire des commentaires sur le besoin en personnel, la gestion du projet et l'ensemble du système envisagé.

La ventilation du coût approximatif de la phase 1 du projet est:

Forestier	14 000 $
Surveillant	6 000 $
Aides-arpenteurs	1 500 $
Contremaître élu	2 000 $
Récolte de bois 500 tonnes anhydre @ 56,21 $ la tonne anhydre	28 000 $
Expert-conseil chargé de l'évaluation, première et deuxième étapes	15 000 $
Imprévus	10 000 $
	76 500 $

Cette étude a été effectuée par B.H. Levelton & Associates Ltd., W.C. Edwards, Woodland Resource Services Ltd. et H.A. Olson pour le Fort Ware Band Council et le ministère des Affaires indiennes et du Nord Canada (MAINC) à l'aide d'une subvention du MAINC et du Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada.

I. INTRODUCTION

A. Background

Fort Ware is a Reserve which lies 440 km north northwest of Prince George, 280 km north northwest of Mackenzie and 230 km southwest of Fort Nelson. The community itself is located on the north bank of the Finlay River and has a population of some 170 people.

Fort Ware is a remote community accessible by air year-round and by water when the Finlay River and Williston Lake are ice-free. Increasingly, air travel is becoming the preferred mode of access because of its reliability throughout the year and short travel time.

The community consists of some forty residences, a school and associated teachers' residences, a store, a church, a post office, a nursing clinic and miscellaneous other buildings. A community well has been drilled and work is scheduled for 1984 to install a reservoir, a water distribution system and three washhouses. These facilities will supply the residents of the community with running water and access to showers and clothes washing facilities. Coordinated with this work is the installation of overhead power lines from a generator system near the school to supply the pumphouse and the three washhouses with electricity.

In 1983/1984 under the direction of I & NA, a generator system was installed to supply the school, three teachers' residences and the water system equipment with power. This facility consists of three diesel electric generators each having a continuous rated output of 44 kW. These units are automatically controlled to come on-line sequentially as demand increases to a maximum continuous load of about 132 kW. The power is produced at 120/208-Y volts, 60 Hz.

Stand-alone diesel electric generators are also operated by the Band to satisfy the power needs of the store and nearby buildings and by Health and Welfare Canada to satisfy the power needs of the nursing clinic. The total capacity of these two systems, neglecting back-up units, is 26 kW.

Diesel fuel for the generators is obtained from Mackenzie and delivered usually via a combination of water and air transport. The delivered price of recent diesel fuel shipments has ranged from $0.65 to 0.74/L for government users, to $0.84/L for the Band. Delivered prices vary with the mode of delivery as well as the bulk fuel price.

I & NA is considering supplying all residents of Fort Ware with electricity. This power delivery network would be an expansion of the system planned for supply of the community water system and washhouses. In addition, a community centre is being contemplated that would offer to the Band members facilities for use as a Band office, recreational areas and exercise areas. If these expansions in services to the residences of Fort Ware proceed, it will mean a substantial increase in electrical demand, and correspondingly, diesel fuel consumption and cost.

Diesel fuel is the sole heating fuel for the facilities maintained by I & NA, specifically the school and the teachers' residences. If the contemplated community centre is built, diesel fuel will most likely be the primary fuel. Wood is used for fuel by all other residents of the community except the nursing clinic which uses diesel fuel for heating.

Most of the employable residents of Fort Ware are unemployed. Some members of the community are self-employed as trappers. Others were once involved in guiding but have since ceased this activity for various reasons. Seasonal work is frequently obtained near Fort Ware and apparently up to 40 men sign up for this work. Other employment available in the community is limited to Federal Works projects, such as the recently active programs of house building and harvesting of fuel wood and to community improvement programs being undertaken by I & NA.

Little success has been achieved with training Band members in nearby centres such as Prince George. Often Band members involved in this training return to Fort Ware before their training has been completed. Substantially better success has been achieved when training Band members in their own community. On-the-job training has been conducted as part of a house building program and with a few Band members assisting with maintenance of the facilities of I & NA. Many young men in the Village have demonstrated a natural aptitude for operating a dozer and a front-end loader at the site and for small-engine operation and maintenance.

Many of the Band members are eager for local employment so they may remain in the community. In the past, young people have reluctantly left the community in search of employment, often returning for social or other reasons. I & NA has recently expanded the school and added a vocational shop area. This coming fall courses will be offered at the school on vocational training in subjects such as small engine repair and other topics of local relevance. The process of selection and development of these courses is currently active.

In summary, Fort Ware is a remote community with a stable population and a total dependence on diesel fuel for generation of electricity and partial dependence on diesel fuel for heating. There are no local sources of employment and, consequently, most Band members subsist on Federal support payments. Most members of the community have no vocational skills but are interested in gaining employment as long as training and employment is available locally. Preliminary vocational training is being introduced at the recently expanded school and can be tailored as required to suit local requirements.

All of the circumstances at Fort Ware suggest an alternative power generating system may be viable for, and beneficial to, the community. Such a system should be able to satisfy the electrical power demand of the community as a whole, reduce or eliminate diesel fuel consumption, and offer employment as well as an opportunity for vocational training. This study considers the feasibility of utilizing a wood-fired steam cycle for generating electricity. Fuel would be harvested locally, offering employment in cutting and delivering fuel and in managing the forest resource. The power plant would offer additional employment

for skilled operators as well as an opportunity for operator training that would also be valuable outside the community. Electricity would be generated to meet all the community's needs, thus reducing diesel consumption to a level required for backup units only. Waste heat from the power plant would be available for space heating and domestic hot water in the school and, possibly, other major users in the community.

Other alternate sources of energy for generation of electricity, specifically, low-head hydro, wind power and extension of the B.C. Hydro grid into the community are impractical for various reasons. Low-head hydro power using the nearby rivers is not viable because of the low water level of the river and freezing conditions in winter. This option has been investigated by I & NA and disqualified from further consideration. Wind power is impractical because of lack of steady winds in the area except at the top of local mountains. Extension of the grid to Fort Ware is uneconomical because of its remoteness and the very high cost (possibly $4.5 million at $16,000 per kilometer) of such an endeavour.

B. Scope of Work

The overall objective of this study is to assess the technoeconomic feasibility of a wood-fired steam power plant for supplying electricity in Fort Ware. All aspects of such an installation were considered, including:

- the existing and future thermal and electrical energy requirements of the community;

- the type, character and availability of wood fuel in the area;

- the best approach to fuel harvesting and forest management to sustain the fuel supply over the long-term;

- the technical complexity/simplicity and reliability of the energy conversion technology;

- the costs of harvesting and delivering fuel, and operating and maintaining the power plant;

- the cost of electricity produced using wood for fuel compared to the cost when using diesel fuel;

- the employment created in the community and the approach needed to motivate and train the local people to operate the plant and fuel harvesting operation;

- the requirements for managing the operation and the manpower supply for the total facility and ensuring its long-term viability.

A steam engine was the main prime mover considered in this study because of its robust construction, minimal requirement for maintenance and long service life. Also, steam engines operate in a manner that is expected to be readily understood by members of the Fort Ware community, which would be trained in its operation and maintenance. For a comparison of costs and capability to fit into a plant suited to the community, a simple steam turbine was also considered as the prime mover, with the balance of the plant remaining unchanged.

II. LOCATION AND DESCRIPTION OF FORT WARE

A. Location and Modes of Access

Fort Ware is a small native Indian community situated on a Reserve on the north bank of the Finlay River between its confluence with the Fox and the Kwadacha Rivers. It lies approximately 440 km north northwest of Prince George, 280 km north northwest of MacKenzie and 230 km southwest of Fort Nelson (Figure II-1).

Fort Ware may be accessed by air, typically from Prince George, Mackenzie and Ingenika, or by water via Williston Lake and the Finlay River. Fort Ware is accessible by air throughout the year. Access by water is limited to the period between March and November when the lake and river are ice-free. This access is often hampered by the presence of large jams formed by forest debris floating on Williston Lake. Wind action frequently moves this debris to the northern end of Finlay Reach, blocking access to the Finlay River. The presence of uncharted sandbars at the mouth of the Finlay River and in the river channel present problems for passage of riverboats from Finlay Reach to Fort Ware.

In recent years, various combinations of air and water shipment of goods have been used by the Indian Band, I & NA and Health and Welfare Canada. These include:

- shipment by air from Prince George or Mackenzie;
- shipment by barge to Deserters Canyon on the Finlay River followed by riverboat shipment to Fort Ware;

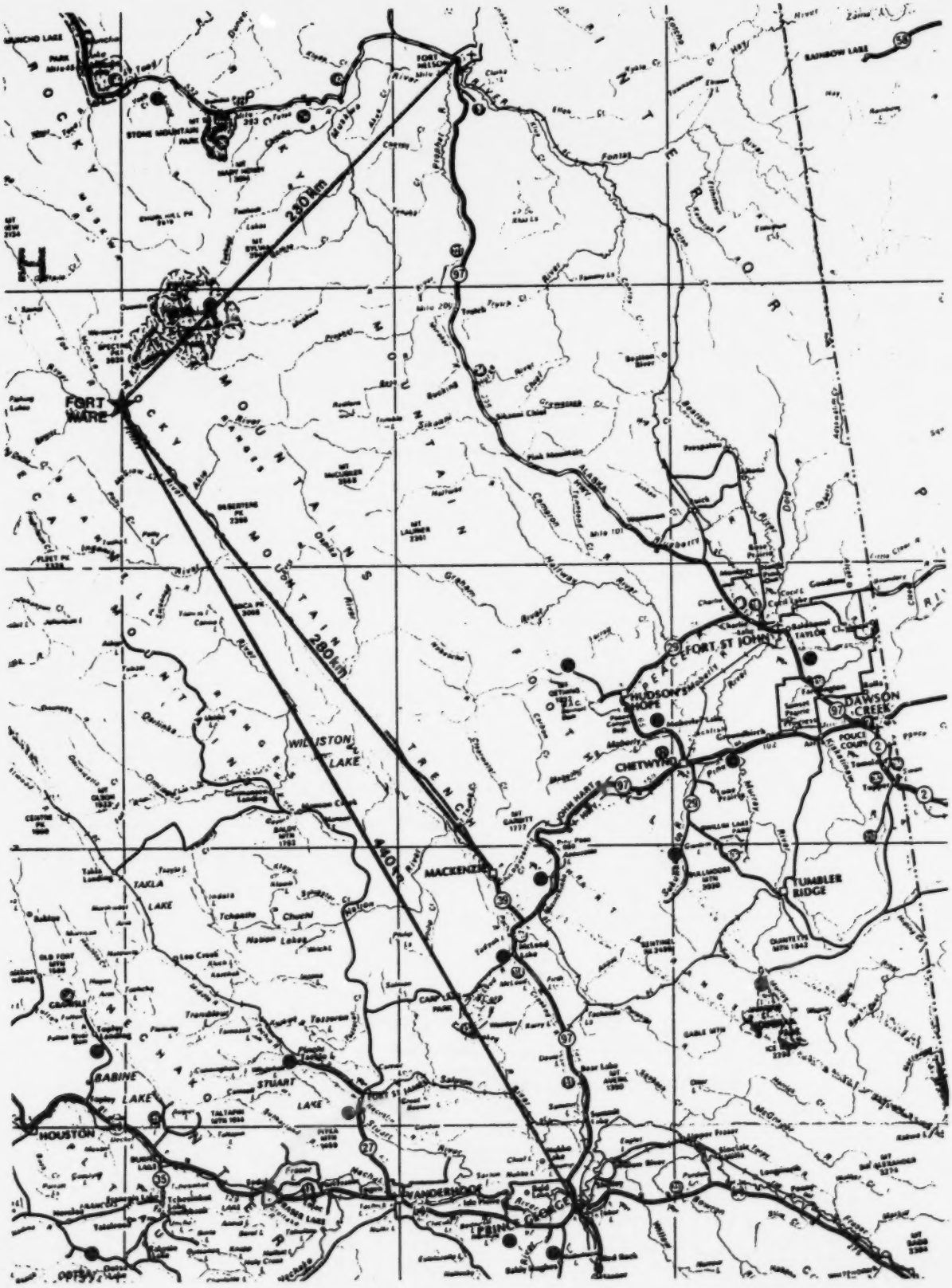


FIGURE II-1. LOCATION MAP FOR FORT WARE

- shipment by barge to Ingenika, near the Ingenika River on Finlay Reach, followed by air shipment to Fort Ware.

Air shipment of fuel to Fort Ware has been found to be most reliable, simplest to coordinate and subject to the least problems, such as pilferage, spillage, etc. Riverboats are becoming increasingly difficult to contract and tend to be uncompetitively priced compared to alternatives.

In at least one case, shipment of heavy equipment has been done by air from an air strip near Pink Mountain on Highway 97 north of Fort St. John. The air strip at Fort Ware, which is 950 m long by 15 m wide, is rated to land aircraft up to a DC3 in size. Such aircraft are able to carry a payload of 3600 kg in a hold measuring 1.8 m in height, 2.1 m in width and 9.1 m in length. To land a Hercules aircraft capable of carrying 23,000 kg, the Fort Ware air strip would have to be enlarged to 1500 m long and 46 m wide.

The Fort Ware Reserve encompasses some 364 ha of land, bounded on the south by the Finlay River, on the west by the Fox River and on the east by the Kwadacha River.

B. Population

As of December 31, 1983, 170 members of the Fort Ware and other Bands were living in Fort Ware on the Reserve. Of this total, seven people were from other than the Fort Ware Band. The total population of the Fort Ware Band living on and off Reserve lands at this same period in time was 221.

Figure II-2 shows the latest available statistics for the population distribution by age group and sex. Even though these data were compiled as of December 31, 1982 they are believed to accurately reflect current circumstances. Comparing the population data for 1983 to that for 1982 indicates that the population was stable over this period. General indications are that young Band members tend to leave the Reserve in search of employment, although many return later for social reasons.

Based on the data compiled for December 31, 1982, there are 43 men and 40 women between the ages of 18 and 65 in the community. This group can be considered as the one potentially available for employment in the community, excluding a small number who are already active in other endeavours.

Few if any men in the Community have a formal education beyond a grade five level and few can read and write. One women has a grade eight education, while one other has reached grade ten. Members of the community in general have functional skills for a wide variety of traditional activities that exceed the skill levels implied by the lack of formal school training. Some members of the community have received vocational training in other communities in British Columbia, though many have returned to Fort Ware prior to completion of the training course, apparently for social reasons.

C. Employment and Traditional Native Activities

Typical vocations of the native Indians at Fort Ware are fire fighting, trapping, guiding, hunting and fishing. No individuals continue to guide and decreasing numbers continue

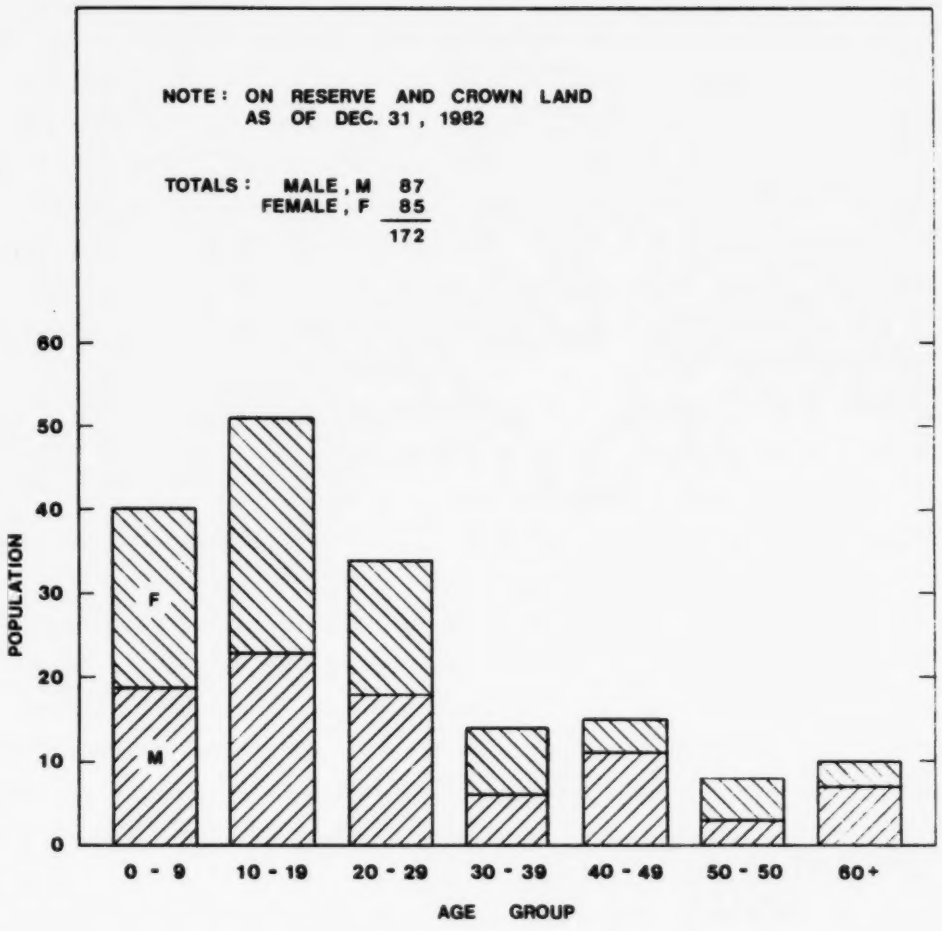


FIGURE II-2. POPULATION DISTRIBUTION FOR FORT WARE AS OF DECEMBER 31, 1982

trapping, though a few are quite successful. Consequently, most individuals on the Reserve are unemployed and rely on federal financial support. Some individuals have worked temporarily with logging companies operating to supply mills at Mackenzie. Members of the community hunt and fish to supply food for personal use. Trapping is done in the period from November to March of the year. The small number of individuals in Fort Ware who operate trap lines on an on-going basis would not be available during the trapping season for other employment.

During a recent federally funded "Need" project, about 14 men signed up for work which included cutting fire wood and building houses for local residents. People interviewed during this study indicated that numerous problems with maintaining a work force were encountered during the house construction program. Reportedly, workers frequently did not report to work at the appointed time, making it necessary to delay work or attempt to find replacement personnel on short notice. Since it was felt to be outside the scope of this study, no attempt was made to establish the cause of the manpower problems encounted during the house construction program. Even though these manpower problems were encountered, several individuals were found to be reliable workers and to be motivated to develop house construction skills. The fuel wood cut under the "NEED" program was for use in the community and was paid for on a piece-work basis. This method of payment was found to be better received than payment on an hourly basis. Past experience has demonstrated that hourly payment for work performed tends to be abused.

Some native workers were used as labourers by the contractor responsible for construction of the new school addition, teachers' residences and the generator building. Again, problems were encountered with poor employee reliability.

A few individuals have been trained to operate a dozer and a back-hoe for the Band and I & NA. These individuals have shown a general aptitude for, and enjoyment of, this type of work. In general, young men in the community appear to have a bent for operation of mechanical equipment, though lack either motivation or proper training to keep this equipment properly maintained. Often equipment is repaired or maintained improperly or by using short-term measures.

Some members of the community are employed as janitors by I & NA to maintain the school, and others are employed as store clerks by the Band Store. A high rate of staff turnover has been observed for these positions.

Mr. Emil McCook, the hereditary Chief and, at the time of this study, the elected Chief, has stated that perhaps forty men are available for work in the community. This is about the number of men who work as fire fighters during the summer and similar in magnitude to the statistics for the men between 18 and 65. The chief indicated that young men in particular would be interested in employment of the type required for harvesting fuel wood and operating the boiler plant, as described in this report.

Based on comments from several individuals who have supervised workers at Fort Ware or lived in the community and are, therefore, familiar with attitudes towards employment, it appears that there are several men and women in the community who would be reliable workers for the proposed facility. A problem to be faced is the lack of interest in continual employment because this interferes with other activities or is contrary to their desired lifestyle. Often individuals employed in previous

projects have been absent from work without notice for highly variable periods of time then have reappeared expecting to be returned to their original position. This type of behaviour poses problems for any employer since the vacant position must be filled immediately by other personnel to continue operation. Although this behaviour does not reduce the total workforce in the community it does require that additional personnel be trained and available on call or on a regular rotating basis to ensure the necessary workforce is maintained. The attitude towards regular work evidenced by past experience has be taken into account when formulating a plan for operating the power plant considered in this study.

D. Layout of the Community

Figure II-3 shows the existing layout of buildings and pathways in Fort Ware. This figure shows the placement of three washhouses and the pumphouse for the domestic water system that will be constructed in 1984. The location of the water distribution piping is defined in the design documents prepared by Urban Systems Ltd. (1984).

The community is composed of the following buildings: thirty-eight residences; Band store; pumphouse; Band office; I & NA school, teachers' residences and power generation facility; Health and Welfare nursing station; and a variety of sheds and other buildings as shown in Figure II-3. Three power generating facilities are present in the community. These are operated by the Band, I and NA and Health and Welfare Canada. The capacities of these systems are itemized in Section C of Chapter III. Power from the Band generator system located near the store is distributed locally as shown in Figure II-3. Power

FIGURE II-3. LAYOUT OF EXISTING AND COMMITTED BUILDINGS AT FORT WARE

from the I & NA generator system located near the school is distributed to the school and teachers' residences. The generator operated by Health and Welfare Canada supplies the nursing clinic only.

A power distribution system to supply electric power to the pumphouse and the three washhouses from the I & NA generator system will be installed in 1984. This is the first part of a total system of overhead lines designed by Pratt (1984) to distribute power to the whole community, including all residences. The timing of this second phase of the electrification process is indefinite. Appropriate allowances have been made in the design of the first phase of the power distribution system for future expansion to include power distribution to the balance of the commuunity.

The existing arrangement of residences and community buildings is quite irregular, with sites being chosen without much consideration for an overall community plan. Recently a community development plan has been suggested by I & NA to assist in the orderly expansion of the Village and to facilitate installation of water and electrical distribution systems. Figure II-4 presents this tentative development scheme, complete with indications of the location of roadways and the planned and potential power distribution network. Placement of these community facilities has been chosen after consideration of areas susceptible to flooding and to prevent potential contamination of the community water supply by effluent from waste dumps and residential privies. The community development plan is only tentative and has been prepared by I and NA for guidance only.

FIGURE II-4. TENTATIVE PLAN FOR FUTURE ROADWAYS AND LOCATION OF PROPOSED POWER LINES

E. Data for Local Climate and the Flowrate of the Finlay River

Climatic data relevant to this study have been obtained from Environment Canada and are summarized in Table II-1. Of note are the low average yearly temperatures and the high value for the number of degree-days, both of which strongly influence the thermal energy requirement of buildings in the community.The climatic data are also relevant to the design of the fuel harvesting plan.

Data for the flowrate of the Finlay River were obtained from the Inland Waters Directorate and are summarized in Tables II-2. These data are required to assess the impact of waste water from a wood-fired power plant on the Finlay River.

Spot measurements for river temperature over the period of record are summarized in Table II-3.

TABLE II-1

CLIMATIC DATA FOR THE WARE STATION FROM

ENVIRONMENT CANADA STATISTICS

	MEAN MONTHLY TEMPERATURE (°C)	MEAN MONTHLY LOW TEMPERATURE (°C)	RAINFALL (mm)	SNOWFALL (cm)	DEGREE-DAYS (°C-day)
January	-19.9	-24.4	0	42.1	1165
February	-12.1	-17.8	0.9	30.3	858
March	- 6.0	-13.0	0.1	13.7	754
April	1.3	- 5.3	6.5	6.9	496
May	6.7	- 1.4	32.3	0.1	344
June	11.4	3.4	43.6	0	210[a]
July	13.6	6.2	68.8	0	132
August	12.8	5.4	49.0	0	160
September	7.8	1.2	42.3	1.2	370[a]
October	1.1	- 3.7	18.3	9.2	519
November	- 8.4	-12.0	1.3	36.0	800
December	-15.2	-19.0	1.7[a]	47.0	1021
Yearly Ave	- 0.6	- 6.6			
Year Totals			264.8	186.5	6829

[a]Estimated by Environment Canada

Source: Environment Canada, 1984

TABLE II-2

ANNUAL EXTREMES OF DISCHARGE FOR THE PERIOD OF RECORD

FINLAY RIVER AT WARE

(Station 07EA001)

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m^3/s)	MAXIMUM DAILY DISCHARGE (m^3/s)	MINIMUM DAILY DISCHARGE (m^3/s)	TOTAL DISCHARGE (dam^3)
1960	--	--	--	--
1961	--	1,500 on May 25	--	--
1962	--	1,200 on Jun 29	32.0B on Feb 23	6,600,000
1963	--	1,130 on Jul 11	32.6B on Mar 11	6,080,000
1964	--	1,720 on Jun 12*	33.1B on Mar 6	6,980,000
1965	--	850 on Jun 3	38.2B on Apr 1	4,970,000
1966	--	1,080 on Jun 18	20.1B on Apr 1*	6,050,000
1967	--	1,120 on Jun 8	24.6B on Apr 3	6,020,000
1968	--	855 on Jun 12	24.9B on Dec 29	5,860,000
1969	--	1,050 on Jun 11	22.0B on Mar 2	5,980,000
1970	--	1,190 on Jun 5	26.6B on Mar 24	6,030,000
1972	--	1,560 on Jun 15	25.3B on Mar 27	--
1973	--	1,000 on Jun 15	29.4B on Apr 1	6,370,000
1974	--	977 on Jul 17	23.8B on Mar 14	6,940,000
1975	--	660 on Jul 3	28.6B on Apr 15	5,010,000
1976	--	1,110 on Jul 1	27.4 on Apr 25	6,880,000
1977	--	929A on Jun 19	26.3B on Mar 28	5,960,000
1978	835 at 15:49 PST on Jun 6*	830 on Jun 6	27.2B on Mar 20	4,550,000
1979	821 at 03:29 PST on Jun 6	807 on Jun 6	21.1B on Feb 23	5,800,000
1980	769 at 15:47 PST on Jun 9	759 on Jun 9	26.1B on Apr 23	6,350,000
1981	--	1,520A on May 28	29.7B on Apr 13	6,740,000
1982	--	1,030E on Jun 13	25.9B on Apr 8	5,330,000
Mean				6,030,000

A - Manual Gauge; B - Ice Conditions * - Extreme recorded for the period of record; E - Estimated

Source: Inland Waters Directorate, 1984

TABLE II-3

SUMMARY OF SPOT MEASUREMENTS OF WATER TEMPERATURE

FOR THE PERIOD OF RECORD - FINLAY RIVER AT WARE

(STATION 07EA001)

MONTH	WATER TEMPERATURE (°C)			
	NUMBER OF READINGS	RANGE OF YEARS OF RECORD	RANGE	AVERAGE
January	13	1963 - 1980	0 - 0.5	0.1
February	6	1964 - 1975	0 - 0.5	0.2
March	12	1963 - 1982	0 - 1	0.2
April	7	1964 - 1981	0 - 4	1.5
May	8	1962 - 1982	1 - 6.5	4.1
June	10	1962 - 1982	5.5 - 9.5	7.6
July	3	1974 - 1980	6.5 - 10.5	9.0
August	7	1962 - 1982	5 - 17	11.2
September	8	1963 - 1980	6 - 13.5	9.9
October	9	1961 - 1980	1 - 5.5	3.8
November	Not recorded	-		-
December	4	1963 - 1973	0 - 0.5	0.13

Source: Inland Waters Directorate, 1984

III. THERMAL AND ELECTRICAL ENERGY REQUIREMENTS

A. Description of Energy Uses in Fort Ware

1. Thermal Energy Uses

The two uses of thermal energy in Fort Ware are space heating and domestic hot water. There are no industrial or commercial uses of thermal energy at present.

(a) Space Heating

Heating of living and working spaces in the community is now done with wood or diesel fuel.

Several buildings maintained by departments of the federal government are heated using diesel fuel. I & NA uses diesel fuel to heat the school, teachers residences' and three recently installed washhouses. The nursing clinic maintained by Health and Welfare Canada is also heated using diesel fuel. The capacities of the various diesel-fired furnaces in place at Fort Ware are tabulated in Section B of this Chapter.

All other heated buildings in the community utilize wood for fuel. These include all native residences, for which wood is harvested individually and burnt in small wood stoves, and the Band store, which is heated using a wood-fired furnace with forced-air circulation.

The heating requirements of the native residences in the community were considered to be too small in magnitude and too scattered in location for supply from a district heating system associated with the power plant. It is conceivable that a district heating system could supply local residences, but this would only be practical if new houses were built close to the plant in high density and were equipped with hydronic heating systems. Because of the potential for temporary plant shutdowns in the winter months, these houses would also have to be equipped with backup space heating equipment, thereby somewhat reducing the benefit derived from being connected to a district heating system.

(b) Domestic Hot Water

Diesel fuel is presently used to heat water for domestic use in the nursing clinic, the school, the washhouses and the teachers' residences. The capacities of the systems in place in the school and teachers' residences are tabulated in Section B of this Chapter.

All other domestic hot water is generated by heating on wood-fired stoves.

2. Electrical Energy Uses

Electricity is used in the school, teachers' residences, nursing clinic, store, Band office, church,

Band storage shed and, temporarily, in two residences near one of the installed generator sets. Except for the residences mentioned above, none of the other residences in the community has access to electric power.

Three generator systems are in place in Fort Ware. One is owned and operated by the Fort Ware Band to supply the store and a few other community buildings. Another unit is owned and operated by Health and Welfare Canada to supply power to the nursing clinic. The largest and last of the three systems is owned and operated by I & NA and presently supplies the school and the teachers' residences. Once distribution lines are in place, the I & NA system will be supplying the pumphouse and washhouses. Electricity is required in the pumphouse for pumps and heating and in the washhouses for lighting, the clothes washing machine and miscellaneous power.

B. Thermal Energy Requirements

1. Space Heating

Diesel fuel is used for heating the Health and Welfare nursing clinic as well as the school and teacherages operated by I & NA. The buildings operated by I & NA were considered to be sufficiently closely grouped to be candidates for displacement of the diesel fuel consumption by waste heat from the wood-fired power generating plant under consideration in this study. For this reason, data were obtained to define the capacity of space-heating furnaces

now in place in these buildings. The nursing clinic was not considered to be a candidate for displacing diesel fuel used for heating because of its distance from both the I & NA facilities and the preferred site for the power plant. The nursing clinic could be considered a candidate if it was moved to a site near the preferred plant location.

Furnace equipment existing or to be installed at the I & NA facilities is listed in Table III-1, showing furnace bonnett capacity and other specifications. For the numbering system for residences Nos. 1 to 3 refer to Figure II-3 of Chapter II. Teacher's residence No. 1 is the residence built in 1973, while Nos. 2 and 3 refer to the west and east side, respectively, of the duplex built in 1983/84. Residences Nos. 4, 5, 6 and 7 have not yet been built but are planned for construction in 1984/85. I & NA staff have indicated that these four residences will be contained in two duplexes similar in design to the duplex containing residences Nos. 2 and 3. Consequently, the furnace equipment for the planned residences has been taken to be identical to that used previously.

For reference, a brief description of the insulation levels and design features of the buildings is given in Table III-2.

The total bonnett capacity for the oil-furnaces presently installed at the school and teachers' residences is 995,320 kJ/h. The total installed capacity increases to 1,488,320 kJ/h after inclusion of buildings planned for construction in 1984/85. The diesel fuel consumption rate when the furnaces are all operating at their rated capacity is 31.57 L/h for the existing buildings, and 46.73 L/h for existing and planned buildings.

TABLE III-1

FURNACES INSTALLED

BUILDING	FLOOR AREA (m^2)	FUEL TYPE	FUEL FLOW AT RATED CAPACITY (L/h)	BONNETT CAPACITY[a] (KJ/h)	CONNECTED POWER (kW)	AIR FLOW-RATE[b] (m^3/min)
School	15 x 30.75	Oil	2.46	76,750	0.19	22.9
Addition	= 461.25	Oil	6.62	206,540	0.37	61.2
Original	12.6 x 19.5	Oil	5.11	159,430	0.25	46.7
School	= 224.9	Oil	6.25	195,000	0.37	57.2
TOTAL FOR SCHOOL			20.44	637,720		
Residences						
No. 1	80.27	Oil	3.55	110,800	0.25	33.1
No. 2	76.5	Oil	3.79	123,400	0.25	36.8
No. 3	76.5	Oil	3.79	123,400	0.25	36.8
No. 4[c]	76.5	Oil	3.79	123,400	0.25	36.8
No. 5[c]	76.5	Oil	3.79	123,400	0.25	36.8
No. 6[c]	76.5	Oil	3.79	123,400	0.25	36.8
No. 7[c]	76.5	Oil	3.79	123,400	0.25	36.8
TOTAL FOR RESIDENCES			26.29	851,200		

[a]80% of the rated input energy and 39,000 kJ/L for diesel fuel except where quoted by the manufacturer.
[b]Air flowrate at 29.4°C temperature rise.
[c]Planned for construction in 1984/85

TABLE III-2

BUILDINGS MAINTAINED BY

INDIAN AND NORTHERN AFFAIRS

BUILDING	FLOOR AREA (m^2)	INSULATION LEVELS	DESCRIPTION
School Addition	461.3	Ceiling - 7 RSI Walls - 4.7 RSI	Wood frame construction with peaked roof. One level buildings with crawl space
Original School	244.8	Ceiling - Walls -	Wood frame construction with peaked roof. One level building with crawl space
Residences			
No. 1	80.3	Ceiling - 2.5 RSI Walls - 1.2 RSI	Wood frame construction, one-level building with below-grade basement
No. 2	76.5	Ceiling - 7 RSI Ext. Walls - 4.7 RSI B'ment Walls - 0.9 RSI Exp. Floor - 7 RSI	Residences 2 and 3 are identical units and form a side-by-side duplex. Each unit has split level construction with a half basement partially below grade. Wood frame construction with peaked roof over half of plan
No. 3	76.5	Ceiling - 7 RSI Ext. Walls - 4.7 RSI B'ment Walls - 0.9 RSI Exp. Floor - 7 RSI	
Nos. 4 & 5[a]	Same as Nos. 2 and 3.		
Nos. 6 & 7[a]	Same as Nos. 2 and 3.		

[a]Planned for construction in 1984/85

The annual heat requirement and diesel fuel consumption of the I & NA buildings were estimated from the furnace capacities using typical values of the excess capacity that is normally allowed during design of a heating system, and using a design temperature difference appropriate for the locale. These calculations are summarized in Table III-3. Excluding residences Nos. 4-7, which have not yet been constructed, the annual heat load of the I & NA buildings is 1,378 GJ leading to an annual diesel fuel consumption of 54,300 L. Including the new buildings to be constructed in 1984/85, this raises the annual heat load to 2,078 GJ and the annual diesel fuel consumption to 81,900 L.

Figure III-1 shows the expected variation of heat load for the school and all existing and planned I & NA residences. These estimates were developed using statistical data for the degrees-day per month.

A community centre is being considered for Fort Ware, but, as yet, its size, building design and functional areas have not been defined. It has been proposed that the community centre be situated immediately to the west of the I & NA education centre. In this location the building is considered to be a good candidate for use of waste heat from the wood-fuel power system for space heating. The design heat loss for a community building having a floor area of 250 m^2 was determined using several simplifying assumptions with regard to insulation levels and building design (Table III-4). These assumptions model design features on the recently constructed teachers' residences and yield a realistic order of magnitude estimate for heat loss and

TABLE III-3

ANNUAL THERMAL ENERGY CONSUMPTION OF THE

INDIAN AND NORTHERN AFFAIRS FACILITIES

BUILDING	FURNACE BONNETT CAPACITY (kJ/h)	ASSUMED[a] EXCESS CAPACITY (%)	DESIGN HEAT LOSS (kJ/h)	ANNUAL[b] HEAT LOAD (GJ/yr)	DIESEL FUEL[c] CONSUMPTION (L/yr)
School	637,720	50	425,150	845	33,000
Residences					
No. 1	110,800	30	92,330	183	7,200
No. 2	123,400	40	88,140	175	6,900
No. 3	123,400	40	88,140	175	6,900
No. 4[d]	123,400	40	88,140	175	6,900
No. 5[d]	123,400	40	88,140	175	6,900
No. 6[d]	123,400	40	88,140	175	6,900
No. 7[d]	123,400	40	88,140	175	6,900
				2,078	81,900

[a]Based on data from ASHRAE Handbook, 1979 Equipment.

[b]Annual heat load = $\frac{GJ}{yr}$ =

$$\frac{24 \times \text{Design Heat Loss kJ/h} \times \text{degree-days (°C-day)} \times 0.8}{1 \times 10^6 \times \text{design temperature difference (°C)}}$$

Design temperature difference = 66°C

[c]Assumed annual average furnace efficiency = 65%

[d]Planned for construction 1984/85

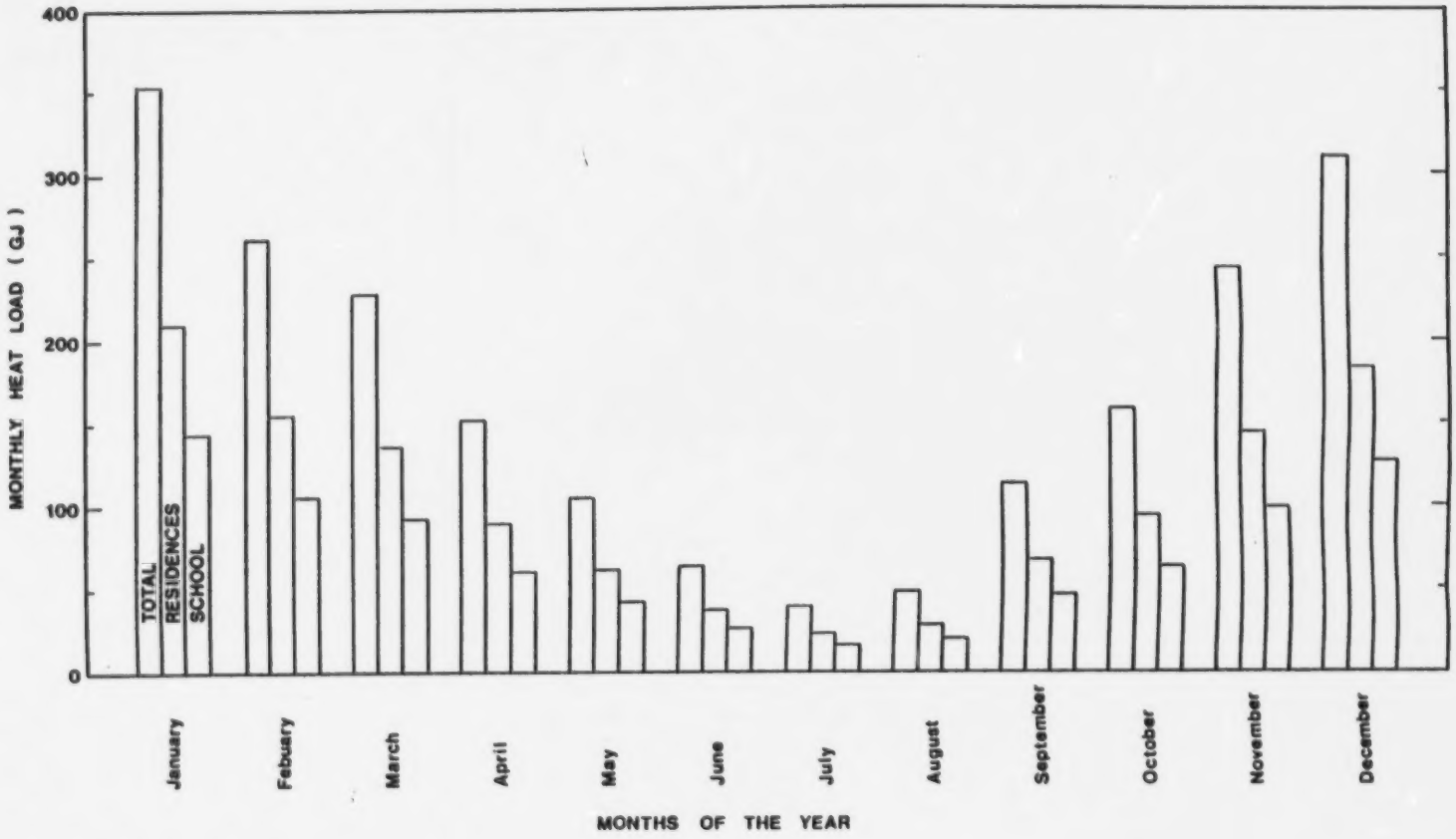


FIGURE III-1. HEAT LOAD BY MONTH FOR FACILITIES OF INDIAN AND NORTHERN AFFAIRS.

TABLE III-4

ESTIMATED HEAT LOAD FOR THE PROPOSED COMMUNITY BUILDING

Design Heat Loss:

Heat Loss Item	(kJ/h)
Walls	8,676
Ceiling	12,531
Windows	24,460
Doors	1,255
Floor	9,899
Infiltration	145,452
Total Heat Loss	202,273

Annual Heat Load (GJ)

January	69	July	8
February	51	August	9
March	44	September	22
April	29	October	31
May	20	November	47
June	12	December	60
			402

Annual Diesel Fuel Consumption 15,852 L/yr

Assumptions for Heat Loss Calculations:

Floor and ceiling area		250 m^2
Perimeter		70 m
Insulation:	Walls	4.7 RSI
	Ceiling	7 RSI
	Floor	7 RSI
Windows:		20% of wall area; double pane and 13 mm space
Design temperature difference		66°C

One-level construction with crawl space.

annual heat load. The assumed building floor area falls between values suggested during interviews with staff of I & NA and residents of Fort Ware, and is intended only as a basis for design calculations in this study. The assumed building design factors should not be construed as formal plans of I & NA or the Fort Ware Band.

The estimated annual heat load is 402 GJ. If this was supplied using oil-fired furnaces it is expected that 15,852 litres of fuel would be consumed annually based on standard ASHRAE calculation procedures and data.

2. Domestic Hot Water

Oil-fired domestic hot water heaters are in place at the school, the three existing I & NA residences, the wash-houses and the nursing clinic. Domestic hot water tanks are not used by any of the native residents. An oil-fired hot water heater will be an integral part of the community centre that is being contemplated. The timing for the installation of this facility is indefinite but has been considered here as a potential contributor to the total domestic hot water heating load. A hot water tank will be installed in each of the four additional residences planned for 1984/85.

The heating load for domestic hot water has been determined for systems at the school and the proposed community centre. The water heating load for the nursing station has been ignored because of its distance from the I & NA facilities and the preferred site for the wood-fired power plant, which is north of the education centre. Also, the water heating load for all I & NA residences has been

excluded from heating load estimates. The two recently constructed residences were excluded because of the existence of solar heating systems for preheating domestic hot water, while the one older residence was excluded simply because of the small size of the hot water tank relative to those in the school and community centre. The heating tanks in the washhouses were also excluded from consideration.

For reference the name-plate capacities of the domestic hot water systems installed in the buildings at the I & NA education centre are listed in Table III-5.

An estimate was made for the hot water consumption of the school using a value of 50 for the total number of students. This is the number of students presently eligible for school enrollment in the fall of 1984 and is slightly higher than the number expected to attend. The number of students attending school in subsequent years is expected to increase slowly, though a four-year projection for school attendance is not presently available from I & NA. Table III-6 presents estimates of water use and associated heat load and diesel fuel consumption for the school. The 54% efficiency of conversion of input fuel energy to hot water used to arrive at fuel consumption was based on data for hot water tanks compiled by B.C. Hydro (Lowe 1984).

An estimate for the hot water use in the proposed community centre was made using standard ASHRAE procedures and data and assuming the centre would incorporate a kitchenette, offices, a television viewing area and a gymnasium. Table III-6 presents the estimates of water use, heat load and fuel consumption (assuming oil-fired hot water tanks are used) and itemizes the fixtures included for analysis.

TABLE III-5

INSTALLED DOMESTIC HOT WATER TANKS

	FUEL TYPE	FUEL FLOW AT RATED CAPACITY (L/h)	TANK CAPACITY (L)	RECOVERY RATE (L/h @ 37.8°C)	CONNECTED POWER (kW)
School Addition and Existing School	Oil	5.30	473	724	0.37
Residences					
No. 1	Oil	3.77	189	505	-
No. 2[a]	Oil	2.84	114	356	0.09
No. 3[a]	Oil	2.84	114	356	0.09
No. 4[b]	Oil	2.84	114	356	0.09
No. 5[b]	Oil	2.84	189	356	0.09
No. 6[b]	Oil	2.84	114	356	0.09
No. 7[b]	Oil	2.84	114	356	0.09

[a]Cold water passes through a solar-heated storage tank (with heat exchanger) for pre-heating prior to inlet to the oil-fired hot-water tank.

[b]These residences are planned for construction in 1984/85.

TABLE III-6

MAXIMUM HOURLY AND AVERAGE DAILY HOT WATER USE

AND HEAT LOAD FOR THE SCHOOL AND COMMUNITY CENTRE

BUILDING	WATER USE		HEAT LOAD			ANNUAL DIESEL FUEL CONSUMPTION[c]
	MAXIMUM HOURLY (L/h)	AVERAGE DAILY (L/d)	MAXIMUM HOURLY (kJ/h)	AVERAGE DAILY (kJ/d)	AVERAGE ANNUAL (GJ/yr)	(L/yr)
School[a]	115	115	28,179	28,179	5.4	260
Community Centre[b]	2,856	2,856	699,579	699,579	122	5,800

[a]Based on 50 students

[b]Based on:

2 private lavatories	46 L/d
1 dishwasher	57
1 kitchen sink	23
1 slop sink	23
2 public lavatories	24
8 showers	2725
	2856

Source: ASHRAE Handbook and Product Directory, 1980 Systems

[c]Based on an annual average efficiency of 54%.

The water use for the community centre is large because of the inclusion of eight showers in the analysis. These will be required if a gymnasium or some similar exercise area is an integral part of the centre. If included, use of this part of the centre by school students and community members is expected to be substantial throughout the school year. Historical data were used for these estimates which apply to facilities in which circumstances of hot water use are probably substantially different from those for Fort Ware. Consequently, there is considerable uncertainty with regard to the accuracy of these estimates though any error will not significantly affect the conclusions of this study. When the functions of the community centre have been more clearly defined it will be possible to re-evaluate the estimates of hot water use.

C. Electrical Energy Requirements

Three diesel-fired electrical generator installations are being used in Fort Ware (Table III-7)

The Fort Ware Band has one 14 kW and one 10 kW unit in place for generating power that is used for lighting in the Band store, the Band office, St. Paul's Church, a storage building and for outdoor lighting in the yard adjacent to the Band store (see Figure II-3). The 14 kW generator is most commonly used, with the 10 kW functioning as a backup unit. The smaller unit is sometimes used as a means to reduce fuel consumption. Power is generated 24 hours per day, seven days per week. Typically 3200 L of diesel fuel are used each month for electricity generation, amounting to 38,220 L annually. The Band is responsible for its own supplies of diesel fuel. A 22,750 L shipment of diesel fuel delivered in November 1983 had a landed price of 83.6¢/L.

TABLE III-7

INVENTORY OF DIESEL ELECTRIC GENERATOR SETS

IN PLACE AT FORT WARE

USER	NUMBER OF EACH MAKE OF SYSTEM	ENGINE MAKE	GENERATOR MAKE	ELECTRICAL SPECIFICATIONS
Fort Ware Band	1	Deutz	Newage Stamford	240/120 volt 73 amps 17.5 kVA (14 kW) 0.8 PF
	1	Lister	Kato	230/115 volt 54.2 amps 12.5 kVA (10 kW) 0.8 PF
IA & ND	3	Volvo Penta Model TD45B	Newage Stamford Model AC234C	208/120 volt 55 kVA (44 kW) 0.8 PF
Health & Welfare Canada	2	Onan	N/A	120/240 volt 50 amps 12 kVA (12 kW) 1 PF

Health and Welfare Canada has two 12 kW diesel units with one maintained for backup. During normal operation, the load on the generator at times reaches its full output capacity. The load on the generator due to the nursing clinic alone is typically 3.6 - 4.8 kW. The balance of the peak load is due to two nearby residences which are temporarily connected to the system. Past experience indicates that the annual fuel consumption of the generator system is 18,184 L. The delivery cost for this fuel has recently varied between $0.34/L and $0.377/L. At a current price of $0.36/L for diesel fuel in Mackenzie, B.C., the landed price varies from $0.674/L to $0.737/L.

The maintenance cost for the Health and Welfare generator system has been averaging $4,000-5,000 per year, exclusive of airfare for service personnel. Maintenance of the units has been an ongoing problem because of unreported scavenging of parts from the backup unit to repair the prime generator. This makes it difficult to plan and schedule maintenance and probably leads to higher costs.

In 1986, Health and Welfare Canada plans to expand the nursing clinic and to replace the existing power generating system with two diesel-fueled 25 kW units. Only one generator will be operating at a time with the other being for backup. Based on a similar unit in use at Takla Landing, B.C., the preliminary estimate of the peak load on the larger generator is 17.5 kW. This demand is considerably higher than that for the existing facility because of the planned use of electric space and hot water heating systems. Health and Welfare Canada has expressed interest in obtaining power from the I & NA generator set now in place.

I & NA has recently had three 44 kW diesel electric generators installed in a dedicated building near the school. The synchronization and sequential startup of the generators to bring them on-line is handled automatically. These units operate in parallel, allowing power output levels of 35 kW, 75 kW and 132 kW with one, two and three units, respectively. Presently, power is generated 24 h/d for use in the school, teachers' residences and for outdoor lighting.

Watt meters are installed to monitor the power delivered by the I & NA generator system. Several spot readings extracted from the log book kept by the operator as well as those recorded during a site visit, May 2, 1984, are given below:

	CURRENT (AMPS)			POWER (kW)		
DATE/TIME	0730h	1500h	2100h	0730h	1500h	2100h
March 8	65	50	73	15	17	15
15	64	55	70	17	15	13
30	60	62	70	13	16	16
April 1	60	56	45	12	15	13
Maximum Recorded Power for April	95	70	58	22	22	14
May 2	40	45	70	-	17	-

Over the period of these measurements, power was being delivered to the school and teachers' residences. The recorded power demand figures are lower than is expected by I & NA staff after school resumes in the fall because of the small number of students presently attending school. The power demand expected by I & NA staff when the school is in session at the education centre is 40-60 kW.

Three washhouses were constructed in 1984 and a water supply system will be constructed in 1984/85 for I & NA. Electricity for these facilities will be supplied from the I & NA power system. Table III-8 summarizes the connected loads for the water system and washhouses. Demand loads, which are also tabulated for these facilities in Table III-8, were estimated using demand factors which attempt to allow for the fact that not all equipment operates concurrently.

The most recent shipment of diesel fuel (1983) for I & NA amounted to 40,860 L and had a delivered cost of $0.654/L. This shipment was made by barge to Deserters Canyon on the Finlay River and by riverboat from there to Fort Ware. Sufficient storage capacity is installed at Fort Ware to avoid winter shipments of fuel except in emergency situations. Additional fuel shipments may be flown in to Fort Ware as circumstances dictate when the lake and river are frozen.

A study has recently been completed (Pratt, 1984) to design an electricity distribution system for Fort Ware that would deliver power from the I & NA generators to the washhouses and the pumphouse in the first phase of installation, and deliver power to all residents in the longer term. The layout of this distribution network follows a preliminary road plan for the

TABLE III-8

CONNECTED LOAD FOR THE WATER SUPPLY SYSTEM

AND WASHHOUSES

DESCRIPTION			CONNECTED LOAD (kW)	DEMAND FACTOR
Water Distribution System				
a) Well pumps Pumps operate singly	2 @ 2.24 kW input [a]		2.87	1
b) Circulating pumps Pumps operate singly	2 @ 2.24 kW input [a]		2.87	1
c) Pumphouse heaters	2 @ 2 kW		4.0	0.5
d) Pumphouse lights and miscellaneous			1.6	0.5
Total Connected Load			11.34	
Total Demand Load after allowance for demand factors			8.5	
Washhouses (3)	Each	Total		
a) Lighting	1.7	5.1		1
b) Miscellaneous	1.0	3.0		0.3
c) Clothes washer	0.7	2.1		0.8
Total Connected Load	3.4	10.2		
Total Demand Load after allowance for demand factors	1.4	7.7		

[a]Efficiency of pump drive motor is 78%.

community (see Figure I-4, Chapter I). The transformer section of the system has been sized to accommodate the rated continuous power output of the power generation system. Three 50 KVA transformers step up the generated voltage from 120/208-Y to 2300/4000-Y. The power lines are capable of handling up to 500 kW, considerably more than the expected load when the community has been completely supplied with electric power.

An estimate of the maximum power demand of the residents of the community was made for this study based on an average demand of 2.5 kW per residence. The residential electrical demand used in this study is 31% higher than the typical peak residential demand for British Columbia (Sigma Resources, 1983). It is also greater than spot readings by I & NA staff for Oweekeno, Nitnanht and Kyuquot which varied from 1.5 to 2.4 kW/residence. The power demand per residence used here is expected to be adequate for the foreseeable residential uses in Fort Ware, but would not be adequate if electrical heaters were used instead of wood for space heating. The initial peak demand for electricity in Fort Ware is expected to be primarily for lighting and small appliances and will, consequently, probably total less than one kilowatt per residence.

There are forty residences in Fort Ware that are eligible for electricity supply, thirty-eight of these being occupied all or part of the year, one being vacant and one being under construction. Based on forty residences and using a demand factor of 2.5 kW/residence, the estimated peak demand is 100 kW. Initially, the peak demand is expected to be much less than 100 kW because the main use of electricity will be for lights and small appliances. The peak demand will increase towards the design value as use is made of electric hotwater tanks, electric ranges and other major domestic appliances.

There is a strong possibility that residents may utilize electric heaters for space heating because of their convenience, rather than continue to use wood stoves. This development is very undesirable if a wood-fired power plant is installed since it would result in a less efficient use of the wood than if it were burnt directly, and it would lead to excessive peak power demand. Possible means of addressing this potential problem are discussed in Chapter IV, Section F, of this report.

If a community building is constructed, power will be required for lighting in office and recreational areas and for kitchen appliances. Using a factor of 50 W/m^2 (Perry, 1976) for light and power demand, which is typical of office requirements, gives a demand of 12.5 kW for a 250 m^2 floor area. This floor area was chosen after consideration of preliminary estimates of I & NA staff, and is the same value used previously when estimating heat load.

Table III-9 contains a summary of the estimates of peak electrical demand loads for the complete community without allowance for diversity of use between user groups. A value of 50 kW has been used for the I & NA facilities, which include the school and the seven existing and future residences. The nursing clinic demand has been set at 5 kW, which is equal to the maximum demand of the existing facility. The thermal energy requirements of the clinic (space heat and hot water) have been assumed to be satisfied by alternate fuels. The demand load of the Band Office and store has been set at 50% of the 10 kW generator now in place. The 50% utilization factor used in this estimate is fairly typical of small diesel electric generators. An allowance of

TABLE III-9

PEAK ELECTRICAL POWER DEMAND FOR FORT WARE

	INTEGRATED PEAK DEMAND (kW)	DIVERSITY FACTORS	PEAK DEMAND AFTER DIVERSITY (kW)
I & NA (School and Residences	50	0.8	4
Native Residences	100	1	100
Nursing Clinic	5	1	5
Pumphouse	8.5	0.9	8
Washhouses	7.7	0.9	7
Band Office and Store	5	0.5	2.5
Community Centre	12.5	0.8	10
Miscellaneous Buildings, Street Lighting	3	1	3
TOTALS	191.7		175.5

3 KW has been made for limited street lighting and for use in miscellaneous buildings not examined separately. All other demand loads listed in Table III-9 are as previously discussed.

The integrated peak electricity demand is estimated to be 191.7 kW. This load applies only if all peak loads are coincident, which will seldom, if ever, be the case. Diversity factors have been used to adjust the estimates of peak demand to reflect the non-coincidence of the peak demands of each community user. With allowance for diversity of use, the peak demand expected for Fort Ware is 175.5 kW. For design purposes, this value has been rounded to 176 kW.

The calculated peak demand after allowance for diversity (176 kW) is expected to occur at or around the time observed for British Columbia as a whole (Sigma Resources, 1983). The peak demand has been observed to occur at 6:00 pm in winter months and at 5:00 pm in summer months. Because of differences in lifestyle and climate, it is possible that the actual time of occurrence of the peak demand in Fort Ware may be different from the Province-wide average. Clarification of the timing of peak demand in Fort Ware can only be done through a monitoring program once the power plant is in place.

The foregoing estimates of peak demand load were derived by compositing current known demand loads and projections based on design factors obtained for other communities. The projected demand loads of native residences and the community centre are subject to uncertainty, although the intent in the demand calculations for these users has been to arrive at conservative design values and ones that are appropriate for the community once the residents have become adjusted to the availability of

electricity. Rapid growth from very low residential demand is expected to occur, perhaps in the first three to five years of operation of the plant, based on the trend of power use for the small native community of Ahousat on Vancouver Island.

Sufficient data are not available to project the future growth in population of the community and, thereby, the growth in residential electrical demand. Recent population data indicate the size of the community is quite stable. Consequently, no allowance has been made for growth in the residential electrical demand for the near future. If the power plant was installed, then the electricity demand and consumption of the community would need to be monitored closely to ensure effective use was being made of the electrical power, and to determine when the facility would have to be expanded to keep up with growth.

For the purpose of the economic analysis conducted later in this study, it is necessary to estimate the annual power consumption. To this end an analysis was conducted of data for peak demand and annual power consumption for electricity generation systems installed across Canada in sizes of 100 to 1000 kW. These data have been gathered and tabulated for the Canadian Electrical Association (Biomass Energy Institute, 1978). For systems of 100-300 kW capacity, the ratio of annual consumption to peak demand is between 2,540 and 2,630 kWh/kW peak. For systems of 100-1000 kW capacity this ratio is fairly consistent, on average being 2,990 kWh/kW peak. Over the various systems investigated the mix of users ranged from 55% residential/45% commercial and industrial to 80% residential/20% commercial and industrial. Using the average value of the ratio for systems less than 300 KW in capacity and the estimated peak demand of

176 kW yields an estimate for the annual power consumption for Fort Ware of 455,000 kWh. This consumption value is equivalent to a continuous annual demand of 52 kW.

IV. DESIGN OF THE WOOD-FIRED POWER PLANT

A. General Design Considerations

In developing a conceptual design for the wood harvesting, wood delivery and power generation operations proposed for Fort Ware a number of general design criteria were identified. These criteria evolved from discussions with members of the Fort Ware Band and with staff of I & NA and attempt to take into account immediate and long-term concerns. In no specific order of priority, the general design criteria may be stated as follows:

- the system should utilize locally available Aspen poplar present in mixed stands near Fort Ware using forest management and harvesting practices acceptable to the Provincial Ministry of Forests;

- the system should be very reliable, and utilize types and scale of technology that are compatible with the apparent aptitudes and lifestyle of the members of the Fort Ware Community;

- the equipment used in the system should be as simple in operation as possible, be labour-intensive rather than highly automated and require little maintenance. Maintenance that is required should be able to be performed with minimal training;

- training of personnel for operation of the system should be able to be undertaken in Fort Ware, preferably, or in Prince George;

- the system should supply all of the community with electricity;

- the system should be designed as a packaged unit that can be delivered to Fort Ware or other remote communities in preassembled and tested modules that require minimal on-site assembly work;

- the system should be optionally capable of supplying select users with thermal energy;

The design of the plant proceeds using the following plant sections for convenience of analysis:

100 Fuel preparation and handling.
200 Boiler and pollution control.
300 Steam engine or turbine with generator.
400 Electrical connection to distribution network.
500 Waste heat removal and recovery.
600 System for supply of makeup and cooling water.

B. Power Plant Capacity

Chapter III concluded with estimates of the thermal and electrical loads present in the community that were to be considered in this study for supply by a wood-fired power plant. To arrive at a practical plant capacity careful consideration was given to the fuel demand of the plant and its effect on the harvesting operation, and to the size of the boiler and its effect on staff training requirements. Using the general design criteria defined previously as a guide to the design of the plant, it was found that both of these factors imposed limits on the size of the power plant.

Fuel supply requirements of the plant were investigated for a range of plant sizes to ascertain the plant size compatible with the available work force and the lifestyle of most members of the community. Harvesting technology for the supply of fuel was chosen that could be readily introduced into the community and that could satisfy the established general design guidelines. A highly mechanized harvesting operation was avoided, at least for the initial plant size, because such a system requires skilled maintenance personnel to keep the equipment functioning properly and is more prone to breakdown than a labour-intensive operation. If the plant must be expanded in the future to meet growth in demand, or to reduce production costs, a more mechanized harvesting operation will be needed. However, by the time such a change in the harvesting operation is needed, personnel will have gained sufficient experience and training to cope with the transition.

The training requirements for the personnel needed to operate the boiler plant in accordance with the Provincial Boiler and Pressure Vessel Safety Act and Regulations strongly influenced the sizing of the plant. A plant size was chosen that required personnel that could be trained in Fort Ware through correspondence courses offered by Provincial educational institutions. Personnel trained in this way would receive on-the-job experience at the power plant following successful completion of the course work and apply for certification by the Province.

The estimate of 176 kW for peak electricity demand of the community over the long-term, after allowance for diversity and including the requirements of the community centre, was presented in Table III-9 of Chapter III. The annual power consumption and

average continuous demand was estimated to be 455,000 kWh and 52 kW, respectively. Power demand of the community overnight will decrease to a very low value, perhaps to in the order of 15-20 kW.

The power demand of the power plant itself must be added to the demand of the community to arrive at the requisite plant output. As detailed in Section F of this Chapter, the peak demand of the power plant, excluding the chipper and associated infeed and discharge conveyors, will be approximately 35 kW. Consequently, the power plant would have to deliver 211 kW to satisfy the total demand in the community at peak times. This peak demand would most likely be of short duration and occur, typically, between 1700 and 1900 hours each day. The expected ratio of peak demand to minimum demand is about 5 : 1.

A wood-fired power plant having a continuous rated output of 175 kW was chosen for analysis. A plant of this capacity appears to have the best fit to the design requirements:

- a plant of this size will be able to satisfy the immediate electrical requirements of the community and the plant itself, since the residents will not possess sufficient appliances to raise the demand to the 2.5 kW/residence used for estimating purposes. Attention to demand load will have to be made during peak demand periods to avoid overloads;

- the plant requires an annual wood supply that can be readily supplied from the surrounding forest using a minimum of mechanical equipment and using skills that appear compatible with the lifestyle and interests of the Band members;

- the plant incorporates a boiler that falls into a category of the Provincial Pressure Vessel Act requiring only one Fourth Class power engineer to act as a chief engineer, and three boiler operators. Use of a larger boiler would shift the plant into the next higher category and require one Third Class engineer and three Fourth Class engineers. This leads to a substantial increase in the level of training required, making such a plant impractical for Fort Ware;

- the plant has sufficient turndown to satisfy the full range of demand loads.

The plant is capable of a power outut of 185 kW, or perhaps higher, when the boiler operates at its rated steam output. The steam engine used in the base-case plant is guaranteed by the supplier for production of up to 219 kW for two hours of every 24 hours without unduly overloading machine components. Such an output would be conditional on the boiler producing steam at a rate 25% beyond the capacity chosen in this study. This may be achievable but could only be ascertained upon selection of the final boiler design.

A base plant was designed to deliver 175 kW of electrical power only. An optional configuration was also considered which involved recovery of a portion of the waste heat from the plant. For this optional design, the thermal loads chosen for supply from the power plant were space heating and domestic hot water heating for the school and the community centre. The thermal loads from Chapter III are as follows:

	SPACE HEAT kJ/h	HOT WATER kJ/h	TOTAL kJ/h
I & NA School	425,150	28,179	453,329
Community Centre	202,273	699,579	901,852
		TOTAL	1,355,181

For design purposes the heat load for these facilities has been rounded to 1,400,000 kJ/h. Note that this figure is based on the design heat load and is, therefore, the peak value. The average annual thermal energy consumption for these facilities has been estimated to be 1,247 GJ for space heating and 128 GJ for domestic hot water. In the latter estimate, the community centre is assumed to be fully occupied 175 days per year, or 48% of the year.

It is expected that due to future growth in the power demand of the community, a plant having a plant capacity of 300 kW will ultimately be required. The timing of the expansion of the plant capacity from 175 kW to 300 kW cannot be specified at this point but would become evident within five years after installation of the initial facility. No attempt has been made to minimize the total cost of the 300 kW facility by allowances in the design of the 175 kW plant for some equipment to be capable of operating at the ultimate plant capacity and for other equipment to be replicated or replaced. Such selective sizing of each part of the plant design would be overly complex and give an imbalanced estimate of the cost of the initial facility. In addition, the costs of expanding the plant in the future could not easily be reconciled because of the differences in the timing of the equipment installation.

A cost estimate has been made for the 175 kW plant. An estimate was not done for the plant after its possible enlargement to 300 kW, primarily because the timing of the expansion of the plant is indefinite. The costs of constructing and operating this larger plant depend on the timing of the project and therefore current estimates for these items would be very uncertain. In addition, it is reasonable to expect that the timing of, and possibly, the need for, expansion of the plant could be delayed substantially by coordinated use of the existing I and NA diesel electric power system to handle peak demand loads.

C. Delivery, Drying and Storage of Wood Fuel

To satisfy the combined annual power consumption of the community and the power plant, 1,700 ODt/yr (1,700 cords/yr) are required. The calculation of this wood consumption value is given in Section F of this Chapter.

The fuel will be transported directly from the woods to the storage area at the plant after being harvested, cut to a length of 1.2 m and split where necessary to a maximum diameter of 20-25 cm. At the plant, the fuel will be allowed to air dry over the summer months to a moisture content of 20%, wet basis. The cord wood will be complete with bark and, because of handling in the wood and storage at the plant will have picked up a minor amount of sand and dirt.

The storage area at the plant has been sized to accommodate a one-year supply of fuel wood. Using a storage area of this size will allow sufficient time for newly delivered fuel to dry to 20 % moisture content or below before being burnt in the boiler. In addition, the fuel may be delivered directly to the

the plant after cutting, avoiding timely and costly rehandling which would result with intermediate storage of the fuel for drying. An added benefit of maintaining a large fuel inventory at the plant is that temporary delays in fuel harvesting and delivery because of weather, manpower shortages or equipment breakdown do not interrupt the supply of fuel to the plant.

Cord wood will be delivered to the plant in nine tonne lots on a rubber-tired wagon where it will be unloaded and stacked. The wagon will be unloaded manually, with the fuel being transferred to a storage pile either directly or with the aid of a tractor equipped with front forks. The wood will be stacked in a total of 32 rows, 35 m in length, that are located on both sides of a fuel delivery roadway. The fuel piles have a 2.5 m height and 2.4 m width; that is, a width equal to two 1.2 m wide rows side-by-side. A 0.6 m air space is left between each 2.4 m wide row to provide ventilation needed for drying.

The land area occupied by the fuel storage piles amounts of 3,318 m^2, or about 0.33 ha, without allowance for the central roadway or clearance around the periphery of the storage area.

D. Siting and General Layout

The location of the plant relative to the school, proposed community centre and power distribution lines is shown in Figure IV-1. This figure also shows the planned route for fuel delivery, utilizing the tentative road plan for the community suggested by I & NA. The chosen plant site has the following merits and is preferable to other sites available in the community:

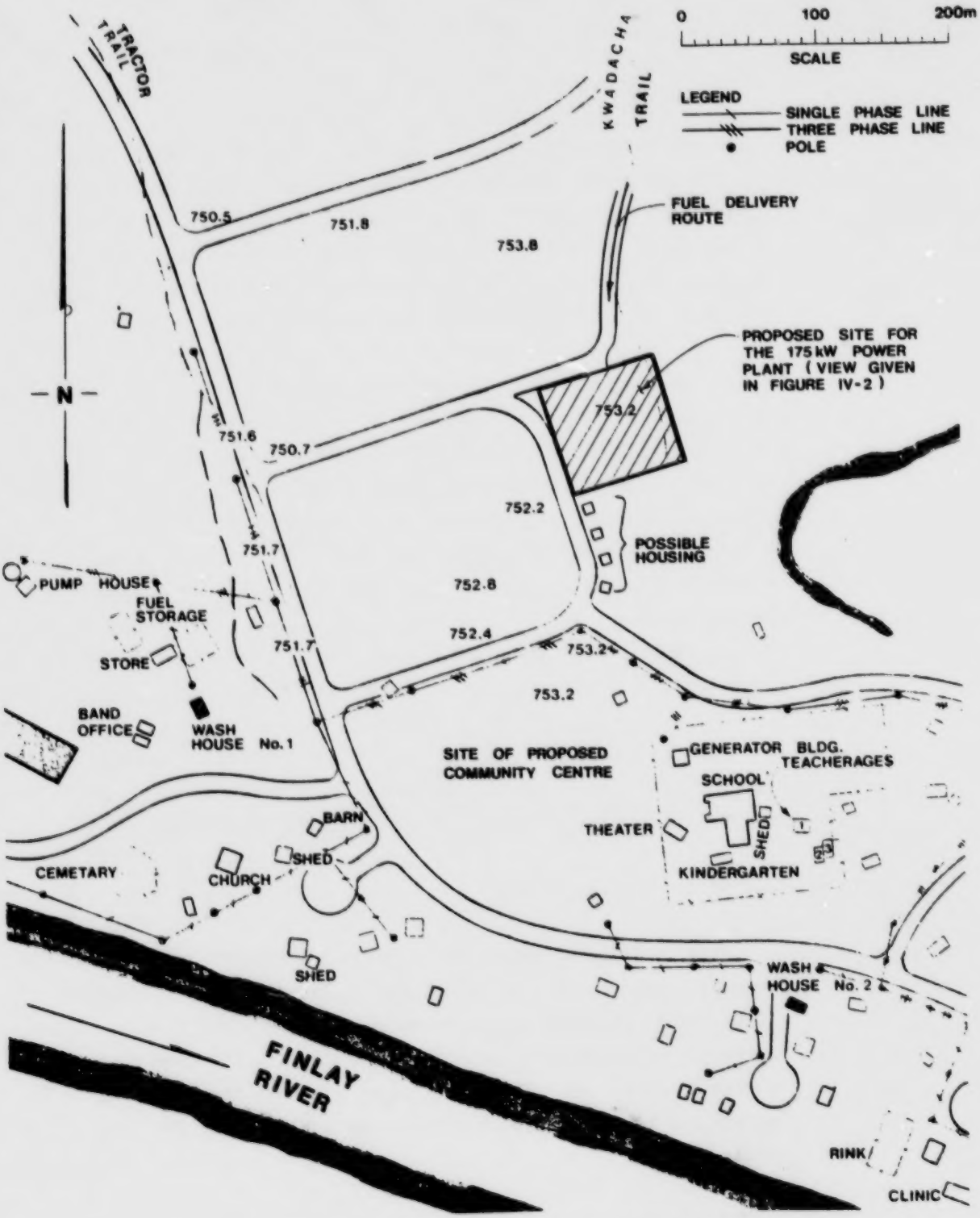


FIGURE IV-1. THE PREFERRED SITE FOR THE POWER PLANT.

- the land is presently unoccupied and use of this site would only utilize three house sites tentatively planned by I & NA;

- the plant site is on the planned eastern boundary of community development, thereby reducing the impact of the plant on residential growth and reducing possible disturbance of residents by noise and dust associated with plant operation and fuel delivery;

- the site is close to the planned power lines, simplifying and reducing the cost of connection;

- the location keeps to a minimum the distance for delivery of heat to the school and community centre;

- cooling water and makeup water may be pumped from an aquifer below the site without affecting the community water supply.

The lay of the land selected for use as the plant site is shown in Figure IV-2 looking southward towards the school along the Kwadacha trail from the view point shown in Figure IV-1. This site could be easily cleared and would need minimal infilling to make it suitable for plant construction and fuel storage.

The general layout of the functional areas of the plant are presented in Figure IV-3. The total land area required for fuel storage, roadways, power plant and electrical equipment, with a reasonable allowance for a clear space around the plant, amounts to 0.77 ha (1.9 acres).

FIGURE IV-2. PHOTOGRAPH TAKEN LOOKING SOUTH ALONG THE KWADACHA TRAIL TOWARDS THE SCHOOL.

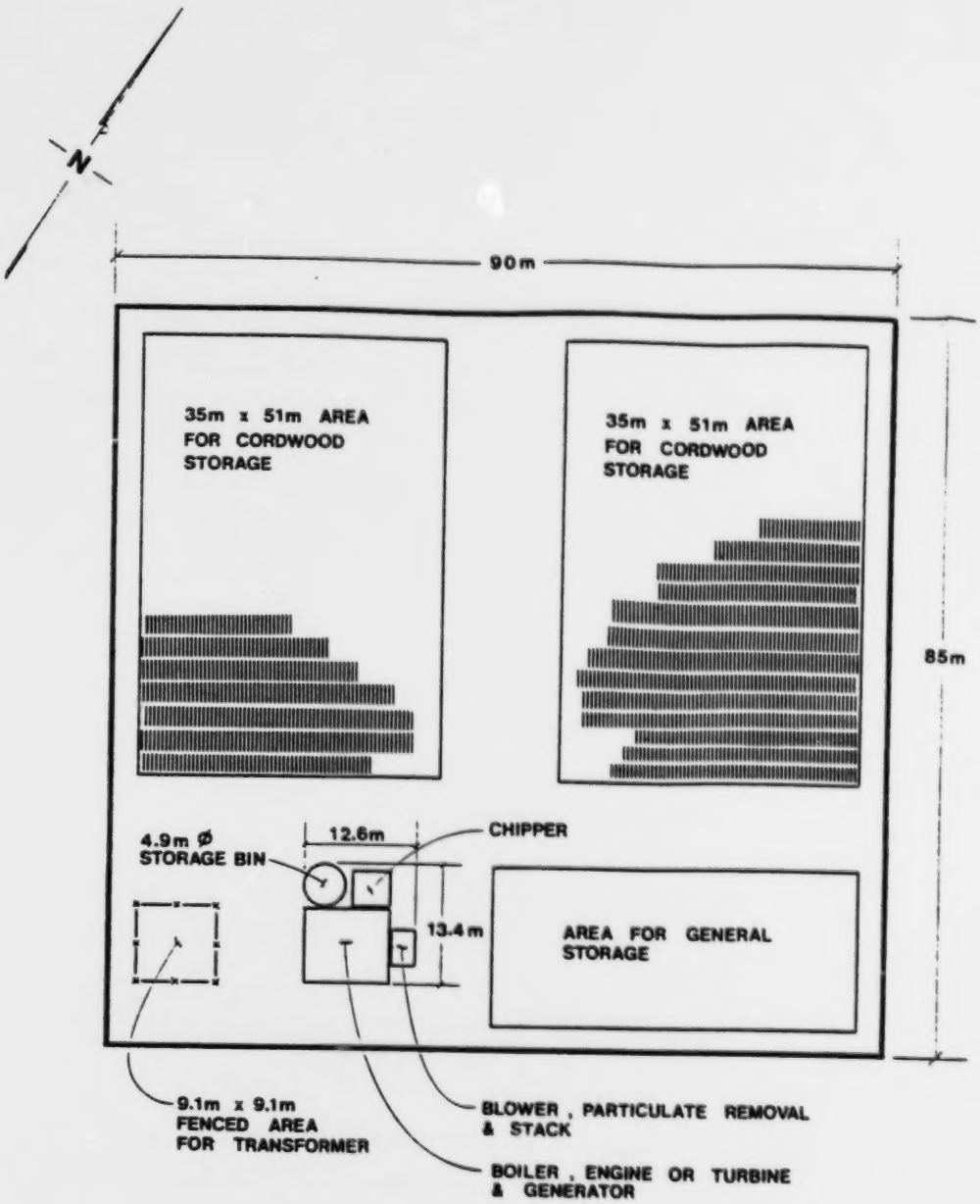


FIGURE IV-3. GENERAL PLANT LAYOUT.

E. Selection of Plant Equipment

The following discussion covers the selection and sizing of equipment comprising the power plant. Three cases are presented:

- a base case design for the power plant which includes use of a steam engine to generate electricity, but excludes recovery of heat rejected by the condenser for use in the community;

- an optional design in which electricity is generated using a steam turbine with the balance of the plant remaining the same as in the base case;

- an optional design in which electricity is generated with a steam engine and heat rejected by the condenser is recovered to supply thermal energy to the school and community centre.

Material and energy balances for the various plant designs indicated above are presented in Section F of this Chapter.

Capital and Operating Costs, respectively, are discussed in Sections H and I.

Figure IV-4 presents a block diagram of the base case plant which identifies major process equipment. This diagram is based on the fuel being delivered as cordwood having a maximum diameter of 25 cm and a nominal length of 1.2 m. The cord wood is recovered from storage using a farm tractor equipped with front forks, and fed to a chipper on a vibrating conveyor. Steam is generated dry and saturated at a gauge pressure of 1,720 kPa.

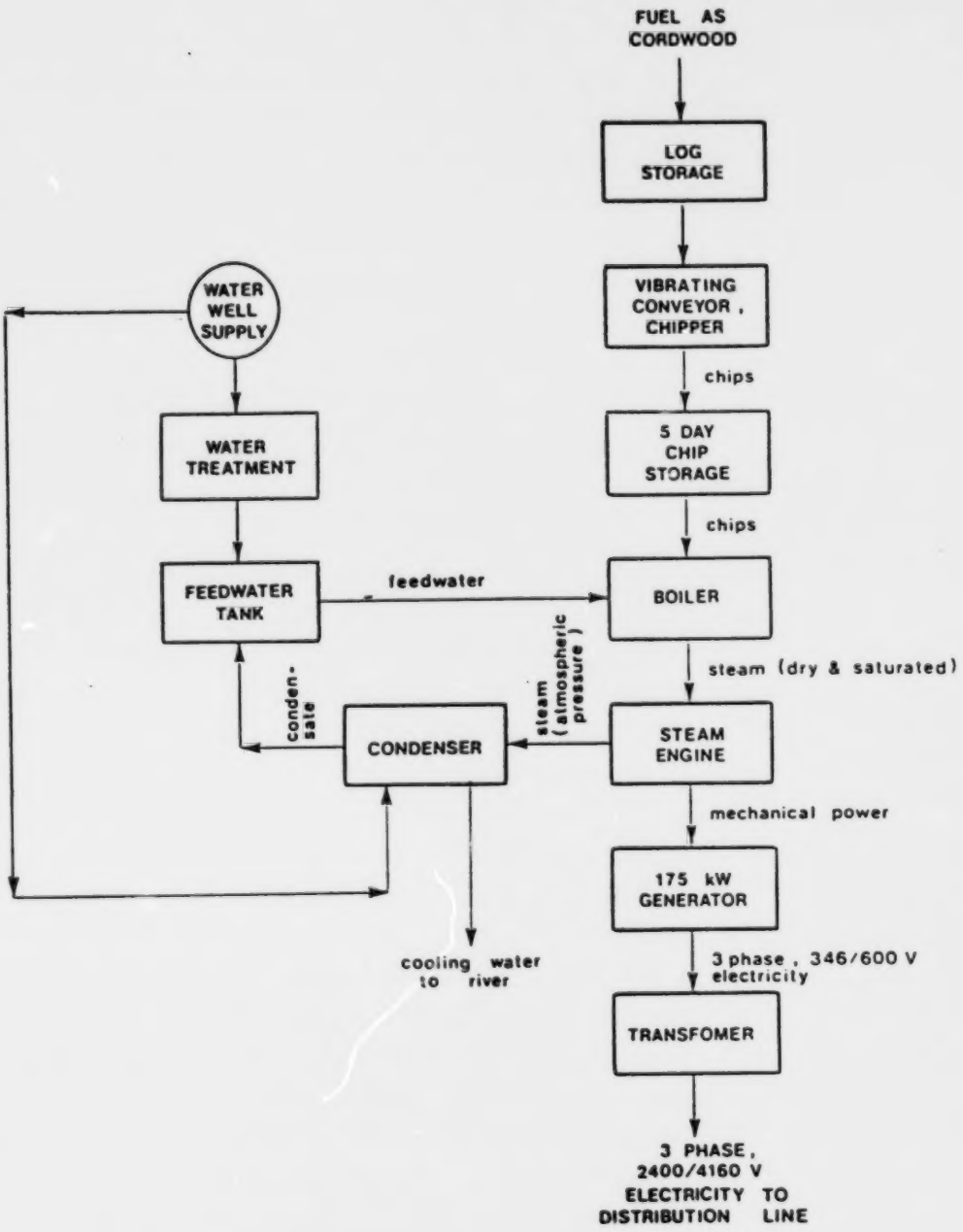


FIGURE IV-4. SCHEMATIC DIAGRAM OF THE BASE CASE POWER PLANT.

The steam engine discharge at atmospheric pressure, producing saturated steam that must be condensed for return to the boiler. Cooling water is pumped from a well near the plant to the condenser, heated to 38°C and then discharged to the Finlay River. The discharged cooling water is uncontaminated and at a temperature that meets the provincial objectives for discharges to fresh water.

For the plant in which a steam turbine is used as the prime mover instead of a steam engine, the general design of the plant is the same as shown previously in Figure IV-4 for the base case.

Figure IV-5 presents a block diagram of the optional plant configuration designed for recovery of 1.4 GJ/h of heat from the cooling water to satisfy the thermal loads of the school and community centre. All other elements of the design are the same as for the base case previously indicated. In this design, steam is condensed using a water/glycol cooling circuit that discharges part of this recovered thermal energy to the community centre and school. Since this heat load varies throughout the year, and will be very low in summer, a by-pass has been included in the circuit to allow for coarse adjustment or a total by-pass of the primary heating loop. Separate controls and secondary piping circuits will exist for delivery of heat to these buildings for space heating and domestic hot water. Heated water/glycol is cooled in the heat exhanger to 10°C before return to the condenser. Cooling water is delivered to the heat exchanger from a well near the plant and is heated to 38°C then discharged to the Finlay River. The discharged cooling water is uncontaminated and at a temperature that meets the provincial objectives for discharges to fresh water.

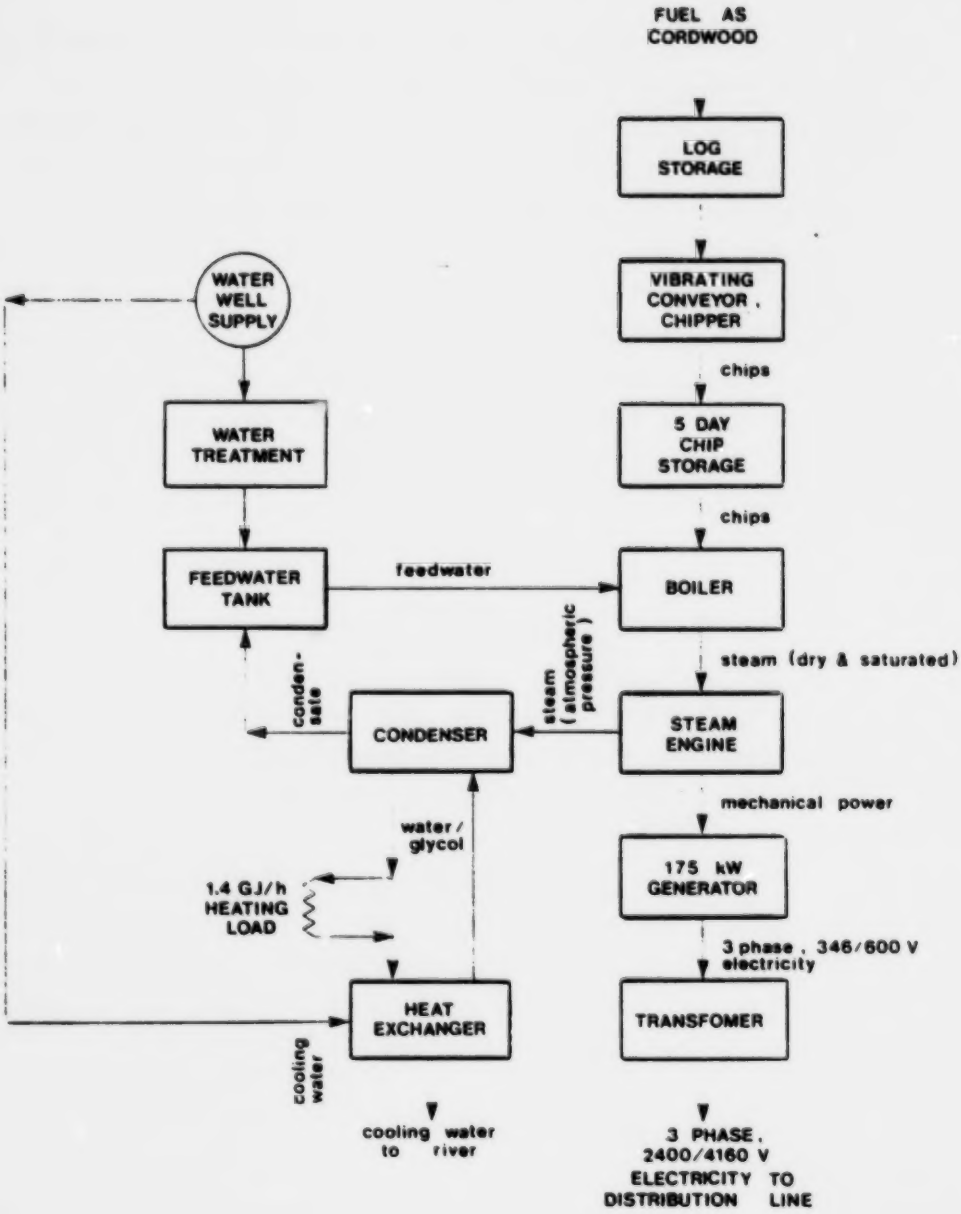


FIGURE IV-5. SCHEMATIC DIAGRAM OF THE POWER PLANT CONFIGURED FOR RECOVERY OF 1.4 GJ/L FROM THE COOLING WATER FOR HEATING APPLICATIONS.

The high hardness of the water which can be pumped from an aquifer below the plant site makes it essential to utilize operating procedures and equipment to avoid scaling problems in the boiler and condenser. For all plant designs considered, makeup water for the boiler must be demineralized externally then further treated within the boiler to minimize scaling and corrosion. For the optional plant design with heat recovery, the water/glycol circuit will be made up using demineralized water and ethylene glycol. This will avoid scaling problems in this unit. In the condenser of the base case plant and the heat exchanger in the water/glycol circuit of the optional plant design, raw water is used. At regular intervals scale depositing in the heat exchangers must be removed.

The maximum practical voltage for a 175 kW generator is 346/600 volts with a Wye connection. This output must be stepped up to 2,400/4,160-Y volts for distribution through the planned overhead power lines. The electrical equipment for this connection is included as part of the total facility.

Appendix I presents an abbreviated list of suppliers of equipment required in the power plant, most of which supplied information for this study. Comprehensive lists of suppliers are given by B.H. Levelton & Associates Ltd. (1980, 1981), and H.A. Simons and B.H. Levelton & Associates Ltd. (1983).

1. Fuel Preparation and Handling

After seasoning of the cord wood in the storage yard over the summer months, the moisture content will have been reduced to a value at or below 20%, wet basis. At 20% moisture content a typical 20 cm diameter by 1.2 m long log

will have a weight of 20 kg. The log weight increases to 31 kg as the diameter reaches the specified maximum of 25 cm.

Two operating conditions are relevant to the operation of the fuel preparation and handling section of the plant, these being the case of maximum power output and the case of average output. The rated continuous output capacity of the plant is 175 kW, requiring a wood feed rate of 0.40 ODt/h. The average power generation of the plant, including the requirements of the community, power plant and wood chipper, is 642,915 kWh/y, or 1,761 kWh/d under continuous operation. This rate of power consumption leads to an average wood consumption rate of 0.19 ODt/h. Relating the average fuel consumption rate to the log weight indicates that 12, 20 cm diameter by 1.2 m long logs must be burnt each hour on average to supply the required energy. At rated plant output, 25 logs/h will be consumed.

The fuel preparation and handling section was designed on the basis that chips would only be produced during daylight hours and, at most, six hours/day, five days/week. The actual chipping time required will vary with power consumption, so work schedules for this activity must be flexible to some degree. This approach avoids the difficulty and hazard of recovering fuel from the storage area under artificial lights during night time and leads to a totally acceptable rate of fuel handling in the fuel yard and at the chipper.

Based on a six hour/day, five day/week schedule, wood must be chipped at an average rate of 1.09 ODt/h. The actual chipping schedule may be adjusted about this value to

suit the operating circumstances that may change daily. For example, higher rates may be found to be easily achieved with local manpower and thus the amount of time spent preparing fuel may be decreased. Alternatively, the plant operators may prefer to operate the chipper over more hours during some days, but less or not at all during other days to achieve a good match with the availability of personnel. In general, the approach taken leads to a desirably flexible fuel preparation system.

Because of the high electric power demand of the chipper its use must be scheduled to occur at times when the community demand is low. The chipper has sufficient capacity to produce the desired quantity of chips during typical off-peak demand periods.

During normal operation, the logs will be transferred from the storage yard to the fuel preparation area of the plant. This will be done by one person using a farm tractor equipped with front forks designed for this purpose. An orderly method of recovery of logs will have to be followed to minimize travel time and ensure that only seasoned logs are delivered to the plant. The arrangement chosen for the storage yard lends itself to easy segregation of unseasoned wood from seasoned wood for six months or more of operation, a time that should be sufficient for the wood to reach the desired moisture content.

The logs are transported to the power plant by the tractor where they are manually fed one at a time to a 43 cm wide by 15 cm deep by 2.4 m long vibrating conveyor. The conveyor discharges to the chipper across a gap left to

allow for discard of any dirt and sand shaken free from the logs. The conveyor is driven by a 1.9 kW electric motor.

A 3-knife, 1.2 m diameter disc chipper suitable for production of 25-40 cm long fuel-quality chips was chosen for the plant. This chipper has a lower cost than one designed for production of pulp chips. It can accept logs up to 25 cm in diameter and has a typical capacity during steady feeding of 3.8 ODt/h. The actual throughput of the chipper will depend strongly on the distribution of log diameters and the rate at which logs can be delivered to it. The typical chipper capacity is about ten times the maximum wood requirement of the plant, a consequence of the requirement to process logs up to 25 cm in diameter. The chipper is driven by a 75 kW, 600 V electric motor.

The chipper is complete with three sets of chipper knives (9 total) and one set of counter-knives. The chipper knives must be sharpened after every one or two days of use to ensure efficient cutting action is maintained and prevent excessive power consumption. A standard and easy to use knife grinding table has been included to hold the knives while they are being sharpened. This grinding table would be used in combination with a standard bench grinder.

The chipper discharges from the bottom into a 300 mm diameter screw conveyor which transports the chips up a 45° incline to the top of the storage bin. This unit would measure 10.4 m in length and be supported every 3 m by structural steel. The conveyor would be driven by a 3.7 kW output electric motor.

The storage bin measures 110 m^3 in size and is capable of holding five days of fuel at the average plant requirement of 0.19 ODt/h. This size of bin will allow sufficient time in most cases for repairs to be made to the chipper, feed conveyor or log-delivery equipment. The bin measures approximately 4.9 m in diameter and 6.1 m in height. Multiple parallel screws covering the bottom of the bin are used to reclaim the fuel and discharge it to a collecting screw conveyor running across the full width of the bin. The bin reclaimer is capable of discharging fuel at a rate of up to 680 OD kg/h (4.2 m^3/h). The maximum rate of discharge required by the boiler is 400 ODkg/h (2.4 m^3/h), allowing substantial excess capacity. The bin reclaimer has a connected power requirement of about 11.2 kW.

The bin reclaimer discharges to a 450 mm belt conveyor which transfers the fuel to the metering hopper at the boiler. The connected power for this conveyor is 0.4 kW.

2. Boiler

The boiler has been designed to deliver sufficient steam for generation of 175 kW of electric power. Future expansion of the plant to, say, 300 kW to satisfy increased power demand would require adding a similarly sized boiler in parallel. This means of expanding the plant increases the plant reliability and allows for continuous generation, although at a reduced rate, when one boiler is shutdown.

The most suitable type of boiler for the plant, given the required steam output and the fact that a boiler of simple design and means of operation is preferred, is a firetube boiler. In this type of boiler hot gases generated in an integral or separate furnace area flow through one or more passes of fire tubes placed within a water-filled shell, then exit to particulate removal equipment and onward to a stack for discharge to the atmosphere. Water is heated and evaporated by conduction of heat through the firetube surfaces. Circulation of water past the tube results from natural convection. Firetube boilers come in several arrangements, such as vertical-tube, inclined-tube and horizontal-tube, with the horizontal-tube type being the most popular. The heating surface on firetube boilers may be arranged so there are up to four passes of hot gases through heating sections of the boiler. Two- or three-pass designs are most commonly used.

Firetube boilers are limited to steam outputs of less than about 3.8 kg/s and to gauge pressures of less than 1,720-2,000 kPa, depending on manufacturer. The limit on steam pressure results because of the need to restrict the thickness of the steel shell to workable levels. The typical upper limit on steam pressure is 1,720 kPa, with higher pressures up to 2,000 kPa only being available on special order.

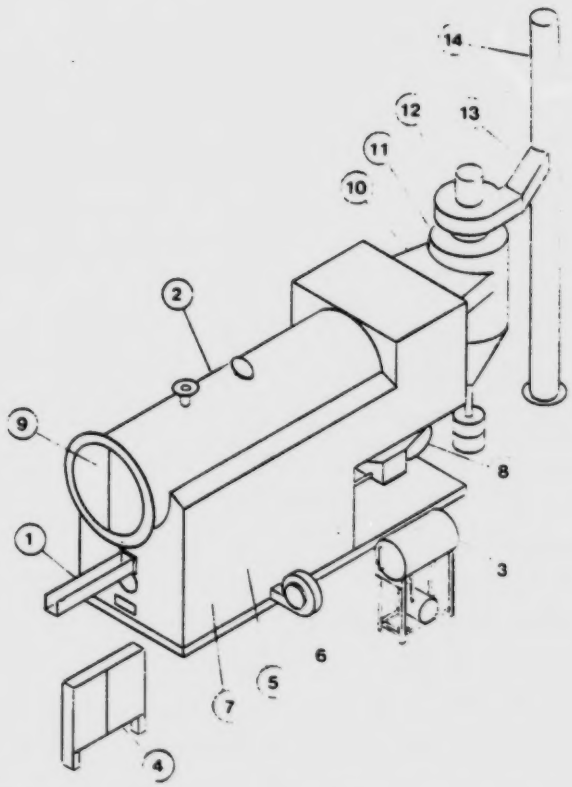
A firetube boiler is best suited to the Fort Ware plant because of its capacity and the need for a boiler that is easy to operate and maintain. Because of the large volume of water present in a firetube boiler, it does not respond quickly to sudden changes in steam demand. Watertube

boilers are preferred for steam pressures beyond the range of fire-tube boilers.

The boiler for the plant has been sized to produce steam at 0.7 kg/s and a working pressure of 1,720 kPa (gauge), or 1,812 kPa absolute, after allowing for the local elevation of 750 m. The boiler is rated for a steam pressure of 2,070 kPa (gauge). The steam requirement of the steam engine/generator for production of 175 kW is 0.66 kg/s. The difference between this steam flow and the boiler design rate allows for blowdown and gives added operational flexibility.

The firetube boiler chosen for the plant is of triple-pass design and has an integral combustion chamber. The arrangement of the boiler is illustrated in Figure IV-6. A metering bin having a 4 hour storage capacity regulates the delivery of fuel to the furnace under automatic control. Ash must be removed from the boiler grate manually and at regular intervals, typically weekly. A cyclone removes particulate matter from the exhaust gases to a level below 0.23 g/m^3 at 20°C, 12% CO_2 in compliance with the Provincial objectives for particulate emissions. The boiler is capable of a 4-5 : 1 turndown, enabling operation with electrical outputs over the range of about 40-186 kW. This range of operation will be satisfactory for Fort Ware.

The efficiency of the boiler depends primarily on the moisture content of the fuel and the level of excess air used for combustion. An excess air level of 30% is near optimal for a firetube boiler burning dry fuel. At this excess air level and with the fuel moisture content of 20%,



1 Fuel Feed Duct
2 Boiler
3 Boiler Feed Water System
4 Automatic Control Panel
5 Combustion Chamber
6 Over and Under Fire Air System
7 Boiler Casing and Refractories
8 Primary Pollution Control System
9 Hot Gas Turn Around Area
10 Boiler Breeching
11 Secondary Pollution Control Equipment
12 Mechanical Draft Inducer Fan
13 Exhaust Duct
14 Boiler Stack

FIGURE IV-6. TYPICAL ARRANGEMENT OF A FIRETUBE BOILER FOR WOOD CHIPS.

wet basis assumed for the seasoned cord wood, the theoretical efficiency of the boiler for a stack gas temperature of 190°C is 76%. Because of the possibility of fuel reaching the boiler at greater than 20% moisture content, use of higher than optimal excess air levels and of other inefficiencies, the boiler is expected to have an average efficiency under actual operating conditions at full load of about 74%. This efficiency value has been used in determining the material balance of the plant at full load. At half load, or less, the efficiency of the boiler is expected to decrease to about 70% under actual operation. This is an approximation since efficiency data for operation at part load are not available. To arrive at the annual wood consumption figure calculated in Section F of this Chapter, a 70% efficiency has been used. If higher efficiencies are achieved in practice, then the annual wood consumption of the plant will be less than the estimated value.

The boiler operates under fully automatic control to maintain steam pressure by adjusting fuel and air feed rates. The air/fuel ratio for the boiler will normally be kept constant. Startup of the boiler is done manually using dry fuel and paper or some other suitable ignition source. The time required for the boiler to increase steam output from the minimum to maximum value is approximately 20 min.

The boiler has a heating surface area of 97 m^2, falling within the range set by the Provincial authorities of 50-100 m^2 whereby one Fourth Class power engineer is required as the plant chief. Since the plant will run continuously, three centified boiler operators for a total of

four workers would be required for 24 h/d operation with three shifts per day and the normal 40 h per shift. Shift workers would pick up eight hours per week of overtime at a rate of one and one-half times the base wage rate. Boilers having a heating surface area of 100 to 500 m^2 require one Third Class chief engineer and three Fourth Class shift engineers. Consequently, boilers larger in size than the one chosen require operators having considerably more training and ones that would have a higher labour rate. This fact was considered when evaluating options for the plant size and it was concluded to be more practical to limit the boiler size to a heating surface of less than 100 m^2 and power output to 175 kW.

The boiler package consists of the following components, having the nominal shipping sizes and weights shown:

COMPONENT	DIMENSIONS (m high x m wide x m long)	WEIGHT (kg)
Boiler	2.7 x 1.8 x 5.9	8,170
Combustion Chamber	2 x 1.8 x 2.7	19,890
Control panel	3.7 x 1.2 x 1.5	910
Stoker	0.6 x 1.2 x 2.1	1,680
Metering bin	1.2 x 1.8 x 0.9	680
Pollution Control Equipment	1.2 x 1.2 x 1.8	4,540

COMPONENT	DIMENSIONS (m high x m wide x m long)	WEIGHT (kg)
Feedwater system	0.9 x 1.8 x 1.2	1,360
6 m stack	6 x 0.3 x 0.3	450
Breeching	0.6 x 3	450
Valves and controls	1.2 x 1.2 x 1.2	450
Structural steel for various supports		4,540
		34,120

The approximate total shipping weight, including crating where required and miscellaneous equipment, is 36,300 kg. Normally, this equipment would be shipped in two standard shipping containers, one measuring 12 m in length, the other 6 m in length.

The boiler package has a total connected power of 26 kW, resulting primarily from the induced draft fan needed for boiler operation, the dual feedwater pumps, and the fuel metering and stoking equipment.

Because of the triple-pass design, the stack gas is exhausted at the relatively low temperature of 190°C. Before discharge, the stack gases pass through gas cleanup equipment for removal of particulate material. The gas discharged to the atmosphere is, therefore, relatively clean and will not cause dust problems in the community.

To keep the boiler design as simple as possible, both to minimize cost and to simplify operation and maintenance,

the boiler does not include a backup burner to maintain operation without wood feed. Such a burner, perhaps fired with diesel fuel, could be incorporated into the boiler if desired. Because the boiler does not have a backup fuel, steam production ceases during manual removal of ash from the boiler grate. About 100 kg of ash per week would be produced from burning wood at the average rate of 190 OD kg/h continuously. Most of this ash would remain on the boiler grate, with the balance collecting in the hopper incorporated into the pollution control equipment. This ash contains potassium, sodium and other useful nutrients for plant and tree growth, and could be used effectively and safely by recycling it to the forest. The removal of ash from the boiler would be a routine chore for the operating engineers and would have to be timed for a period in the week when the community could do without power for two to four hours. Use could be made of the I & NA diesel generator sets during this period to maintain power supply to all or part of the community. Automatic switching gear has not been included in the design to bring the I & NA generators on-line as soon as the wood-fired plant shuts down.

The owner of the boiler must obtain the necessary permits from, and have the completed boiler inspected by the Boiler and Pressure Vessel Safety Branch of British Columbia to comply with the Province's Boiler and Pressure Vessel Act. The first stage in the process is the review of the boiler drawings to ensure they meet the required standards, registration of the design and calculation of the heating surface area that will dictate manning requirements. Subsequently, a construction permit must be obtained before

before construction proceeds. Upon completion of construction the boiler must be inspected and certified as meeting the provisions of the Act, then registered for operation. Subsequent inspections are necessary annually. Inspections by Provincial boiler inspectors for the size of boiler involved would take about two hours.

To ensure safe operation of the boiler it is necessary that it be cleaned internally and inspected on an annual basis by operating personnel. This inspection would be timed to coincide with the inspection undertaken by the Boiler and Pressure Vessel Safety Branch. The major steps in the annual inspection are as follows:

- shutdown the boiler;
- allow the boiler to cool;
- drain all water from the boiler and vent the boiler to atmosphere;
- close or open valves and tag them;
- thoroughly vent the fire side of the boiler;
- clean the water side of the boiler with a wire brush in all accessible areas;
- inspect the water side of the boiler and look for any signs of corrosion pitting or scaling;
- clean the fire side of the boiler removing soot and ash, etc.
- check all refractory in the furnce area for deterioration;
- prepare to close in the boiler by removing all objects;

- close the water side of the boiler, replacing gaskets as necessary and fill the boiler;
- close up the fire side of the boiler;
- restart the fuel supply system and put a small amount of fuel in the boiler;
- ignite the fuel and raise a small fire to bring the boiler up to temperature slowly. Vent produced steam.
- retighten inspection ports, etc.
- restore the boiler to automatic control.

The total inspection and cleaning process for the boiler, including cooling and restarting the boiler, would likely extend over 24 to 48 hours, depending on the buildup of deposits and whether problems are encountered. This shutdown should be scheduled during the summer months when the impact on the community would be minimal. To supply the facilities in the community which could not do without power, such as the residences with refrigerators and electric ranges, the I & NA diesel generators would have to be brought on-line.

The boiler operating personnel would have to conduct various daily, weekly and monthly tests, inspections and adjustments to keep the boiler operating optimally. These chores form a normal part of the training of Fourth class engineers and Boiler Operators and the operating and maintenance procedures specific to the design of the boiler would be thoroughly explained in documentation supplied by the manufacturer.

3. Steam Engine and Generator

The base case plant design incorporates a steam engine for generation of mechanical energy which is in turn transmitted to an electrical generator. This section of the report discussed the various types of steam engines available commercially. A steam turbine was considered as an alternate prime mover for power generation. A discussion of the steam turbine/generator set for this optional plant design is presented in Section E-4, following. The boiler capacity is the same for both prime movers considered.

(a) Performance Characteristics and Suppliers of Steam Engines

The two distinctive types of steam engines available commercially are the counter-flow and uniflow engines. In the counter-flow design, steam enters and leaves at the same end of the cylinder, leading to cyclic heating and cooling of this part of the engine, and significant condensation heat loss and inefficiency (Figure IV-7.). The steam enters at the end and leaves at the middle of the cylinder in a uniflow design (Figure IV-7), avoiding this type of heat loss and achieving a somewhat higher engine efficiency. For example, with inlet steam at 1,720 kPa (gauge) and atmospheric exhaust, a slow-speed (approx 350 rpm), 168 kW_m counter-flow engine has a steam requirement of 16.4 kg/kWh_m. A uniflow engine of the same size has a steam requirement of 12.1 kg/kWh_m. These rates are equivalent to thermodynamic efficiencies of 44% for counter-flow and 60% for uniflow engines; these

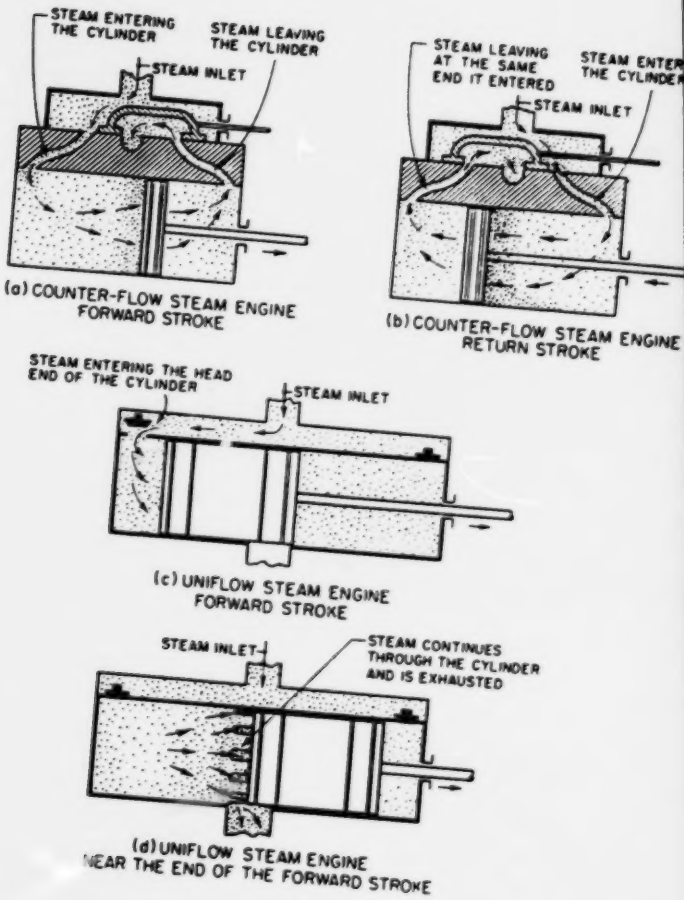

STEAM ENTERING THE CYLINDER
STEAM LEAVING THE CYLINDER
STEAM INLET
(a) COUNTER-FLOW STEAM ENGINE FORWARD STROKE
STEAM LEAVING AT THE SAME END IT ENTERED
STEAM ENTER THE CYLINDER
STEAM INLET
(b) COUNTER-FLOW STEAM ENGINE RETURN STROKE
STEAM ENTERING THE HEAD END OF THE CYLINDER
STEAM INLET
(c) UNIFLOW STEAM ENGINE FORWARD STROKE
STEAM INLET
STEAM CONTINUES THROUGH THE CYLINDER AND IS EXHAUSTED
(d) UNIFLOW STEAM ENGINE NEAR THE END OF THE FORWARD STROKE

FIGURE IV-7. COMPARISON OF STEAM TRAVEL IN CYLINDERS OF COUNTERFLOW AND UNIFLOW ENGINES.

efficiencies are relative to the energy output possible with isentropic expansion of steam in the engine. With inlet steam at 860 kPa (gauge) and the engine exhausting at 69 kPa (gauge) back pressure the steam rates are about 21.9 kg/kWh$_m$ for a slow-speed counter-flow engine and 13.6 kg/kWh$_m$ for a uniflow engine. The substantial improvement in the efficiency of the uniflow design compared to the slow-speed counter-flow design is evident.

High speed counter-flow engines (750-1500 rpm) are available which include features adapted from internal combustion engines. With inlet steam at 1,720 kPa (gauge) and atmospheric exhaust this type of engine with a 16.8 kW$_m$ capacity, has a steam requirement of about 11.6 kg/kWh$_m$. From this it can be concluded that uniflow and high-speed counter-flow engines can operate at similar efficiencies.

Because of the more complex design of the uniflow engine, it is more expensive to manufacture than the slow-speed counter-flow engine. Therefore, the benefit of improved efficiency of the uniflow engine must be weighed against its higher cost when deciding on which engine design is most economical.

Modern steam engines are available with outputs ranging up to about 2,000 kW for all inlet and outlet pressures commonly used for steam turbines. Because steam turbines are more economical in larger sizes,

steam engines are usually seriously considered only for cases in which steam pressures and output power requirements are low. When use of steam engines was popular for all manner of applications, they were available in a wide variety of configurations and with several types of governors and steam inlet valves. Limited demand for steam engines in recent times, except to a noticeable degree in underdeveloped countries, has resulted in a dramatic reduction in the number of suppliers of steam engines and an associated reduction in the variety of design options that can be obtained. Thorough discussions of the development of the steam engine, the function and designs of engine parts, performance characteristics and maintenance requirements among other subjects have been given by Woodruff and Lammers (1977) and Lyle. Brief reviews of the current status and suppliers of steam engines have been given by Edwards and Cotton (1982) and SNC (1981).

Compared to steam turbines, the main advantages and disadvantages of steam engines are as follows:

Advantages:

- excellent torque characteristics;
- easily started under heavy load;
- reversible engine direction;
- suitable for highly variable or slow speeds;
- more economical in small sizes of, say, less than 500 kW;
- very low maintenanc;
- rugged construction.

Disadvantages:

- equipment is bulky;
- high thermal losses;
- require a large flywheel to smooth out speed fluctuations;
- lubricating oil for cylinder rings must be injected with steam.

Some fifteen suppliers of steam engines are listed in the 1982 Thomas Register of Companies. These companies were contacted by mail to determine the suitability of the company's equipment for driving a generator having an output of 150-200 kW. From this survey only two companies, Skinner Engine Co. of Erie, PA and Spillingwerk of Hamburg, West Germany were able to offer proven commercial equipment for electricity generation. Both of these companies were contacted further to obtain detailed information on engine design, performance and cost.

Skinner Engine Co. manufactures counter-flow and uniflow designs of steam engines and markets them world wide. Standard counter-flow engine models for generation of electricity come in sizes ranging from 5 kW to 125 kW based on inlet steam at 860 kPa (gauge), dry and saturated, and 69 kPa (gauge) back pressure. These engines are available for inlet steam pressures up to 1,720 kPa (gauge) and can be operated with the engine discharging to vacuum, atmospheric pressure, or elevated pressure. Back pressure discharge is usually preferred in installations where cogeneration of electricity and either process steam or heat is desired. Uniflow

engines are more efficient than counter-flow engines and are, therefore, more popular in sizes of 150 kW or larger when steam consumption is a concern. Standard models of uniflow engines for generation of electricity are available in sizes from 200 kW to 1000 kW. Common inlet steam conditions are 1,030 kPa (gauge) and 2,070 kPa (gauge), dry and saturated. Uniflow engines may operate with inlet steam pressures up to 4,820 kPa (gauge). Exhaust conditions typically vary from 6.5 kPa (absolute) to 80 kPa (gauge).

Skinner counter-flow engines operate at up to 600 rpm for the smallest output capacities and, typically, 355 to 400 rpm for sizes larger than 30 kW. The speed of uniflow engines decrease from 400 rpm for units with 200 kW output to 327 rpm for units with 1000 kW output.

Both counter-flow and uniflow engines offered by Skinner are, of necessity, of heavy construction and, therefore, require substantial foundations. Concrete foundation requirements for uniflow engine/generator sets vary with model between 42.5 dm^3/kW to 71.9 dm^3/kW.

Skinner counter-flow engines are available with a wide variety of standard and optional features. Counter-flow engines are pressure lubricated to minimize wear of engine parts and require injection of oil with inlet steam at a concentration of about 12 ppm to minimize wear of cylinder rings needed to reduce steam leakage past the cylinder. Flow of steam to the engine cylinders is controlled using a piston valve (Woodruff

and Lammers, 1984). The engine speed is normally controlled using either a mechanical or hydraulic governor.

Skinner uniflow engines are also available with numerous features. The main components of the engine are shown in cross-section in Figure IV-8. Note that moving parts of the engine are pressure lubricated and that cylinder rings are used to minimize loss of steam past the cylinder. Lubricating oil must be injected with the steam to reduce ring wear. With this engine type hydraulic or electronic engine speed controls may be used. Injection of steam to the engine cylinder is controlled by a cam-driven poppet valve which is less subject to wear than sliding valves, is fast-acting and can be easily adjusted. Uniflow engines require a heavy flywheel to produce a steady output shaft speed.

Spillingwerk manufactures high-speed engines designed for modular assembly into a wide range of engine output capacities. The engines are of counter-flow design and operate at speeds ranging from 750 rpm to 1500 rpm, considerably higher than conventional steam engines such as those manufactured by Skinner Engine Co. Spillingwerk has purposely developed high-speed engines of modular design to increase the output per unit of engine displacement and produce an engine that gives the user a means of easily increasing the engine output.

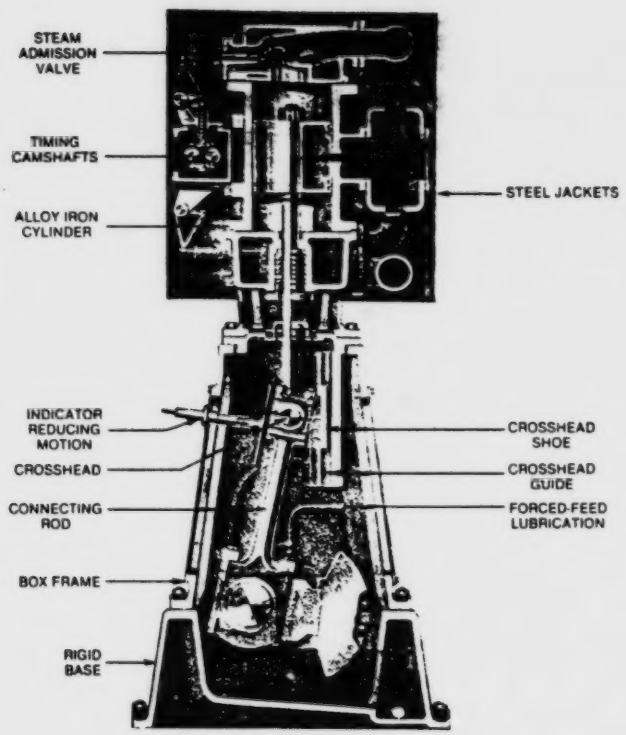


FIGURE IV-8. CROSS-SECTION OF A VERTICAL UNIVERSAL UNAFLOW STEAM ENGINE MANUFACTURED BY SKINNER ENGINE CO.

Key features of the engine are the use of lightweight pistons, a short engine stroke, counter-rotating crankshaft and camshaft, modular construction with precision machined crankshaft and other crankcase mating surfaces for accurate coupling of one-cylinder modules and standardization of engine parts.

A two-cylinder Spillingwerk engine is shown in Figure IV-9 in cross-section to illustrate the main components of the engine. The engines use a short stroke, varying from 70 mm for their small engine model (Type 7) to 126-140 mm for their large engine models (Types 12 and 14). A piston valve driven by a camshaft is used to control flow of steam to and from the cylinder. The piston valve is located immediately adjacent to the engine cylinder to maximize engine efficiency. A unique feature of the design is the use of a water blanket on the top of the crankcase to prevent transfer of heat from the engine casing, which may be at 200°C, to the crankcase. This has the benefit of reducing thermal expansion of the crankcase and avoiding thermal degradation of the lubricating oil. A flywheel is needed to stabilize output shaft speed.

The advantages of high speed engines are:

- the engines are more compact and weigh less than conventional lower-speed designs;
- output shaft speeds are steadier;
- the engine reacts quickly to load changes;
- the engines may be direct-coupled to a generator or, alternatively, need use of less gear reduction to be coupled to standard generators;

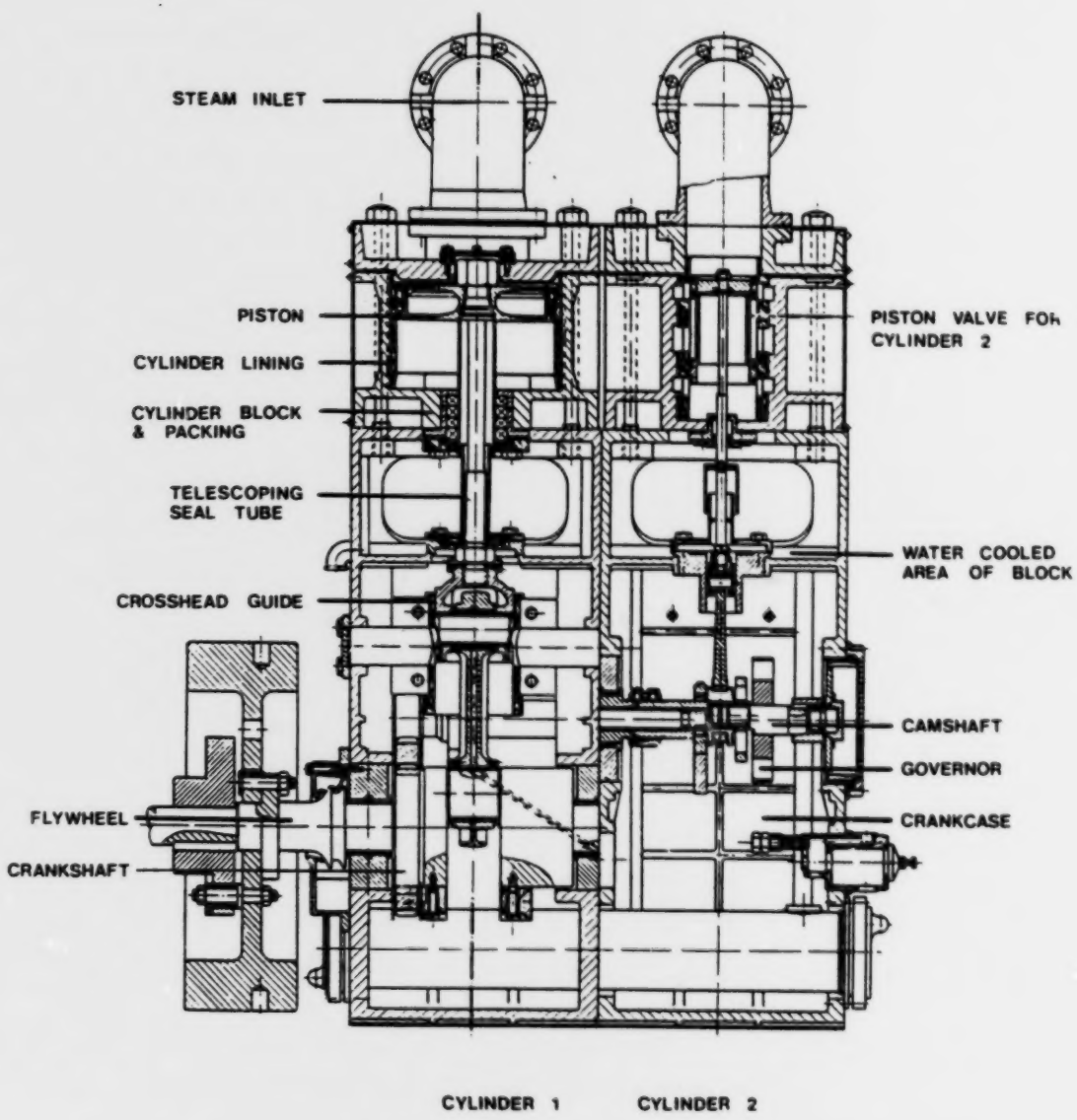


FIGURE IV-9. CROSS-SECTION OF A TWO-CYLINDER SPILLINGWERK STEAM ENGINE.

- part load performance is claimed to be more efficient than for conventional steam engines.

The advantages of a high speed engine must be weighed against its negative characteristics when comparing it to conventional steam engines:

- because of high speed, the engines are less tolerant to the presence of water in the engine cylinder that may result from boiler carryover, condensation as steam enters the cylinder, or operation with a condensing exhaust;8
- wear of moving parts will be higher because of the higher engine speed;
- the engines have a higher capital cost.

Engine efficiencies vary with inlet and outlet steam conditions and with model of engine. Based on steam consumption data for electrical outputs of 150-200 kW, with inlet steam at 1,720 kPa (gauge) and atmospheric dicharge, Spillingwerk engines appear to be more efficient than uniflow engines in this size range.

Because of the high engine speed used, more lubricating oil must be injected with inlet steam than normally is done for slow-speed at the same steam conditions. The oil concentration with steam must be kept at about 70 ppm. About one-half of this oil exits with exhaust steam.

Spillingwerk markets three engine models, Models 7, 12 and 14, that are avilable as mechanical or generator drives. When coupled to a generator, the Model 7 engine, operating at 1500 rpm, produces 27 to 134 kW with one to five one-cylinder engine modules, respectively. In the same configuration the Model 14 engine produces from 110 to 540 kW with one to five modules and operating at 750 rpm. Operating at 1000 rpm, the Model 12 engine produces from 135 to 800 kW with one to six engine modules. In all cases the first and subsequent engine modules for each model have the same output capacity. Modules of the engines may be coupled at the factory or added later as needed by the user.

The Spillingwerk engines are designed to be as dynamically balanced as possible. This reduces the foundation requirements needed for engine generator sets. For the maximum output from each engine model the concrete foundation requirements are typically between 40 and 50 dm^3/kW. This is somewhat lower than that required for Skinner engines.

(b) Selection and Sizing of the Engine

The steam engine considered in detail in this study was selected to operate with the previously specified inlet steam conditions of 1,812 kPa, dry and saturated (207°C), and with the exhaust at atmospheric pressure (92.3 kPa). The continuous rated output of the engine/generator set was chosen to be 175 kW after consideration of the power demand expected from the community and the constraints associated with fuel harvesting

operations and boiler operator training and certification. An overall consideration was to minimize the initial cost of the plant.

Both Skinner Engine Co. and Spillingwerk supplied cost quotations for a complete steam engine/generator set designed to operate under the specified inlet and outlet steam conditions, and for producing 175 kW continuously. Included with the cost quotations was a relatively detailed description of the operating characteristics and maintenance requirements of the associated engine designs. For similar complete engine/generator sets, not crated or otherwise prepared for shipment, equipment cost ranged from $588/kW (US $444/kW) for the counter-flow engine to $1,114/kW (US $840/kW) for the uniflow engine available from Skinner Engine (fob Erie, PA) and was $746/kW (DM 1,716/kW) for the counter-flow engine from Spillingwerk including seaworthy packing (fob Canadian port of entry).

The cost quoted by Skinner included inlet and exhaust steam separators, steam engine, shaft speed increaser, engine, generator, skid-mounting and engine controls. Spillingwerk quoted for similar equipment except for the exhaust steam separator, which was functionally replaced by a condensate tank with integral oil separator.

Weighing heavily the need at Fort Ware for plant equipment of simple design, very low maintenance, highest possible efficiency for the chosen steam conditions to minimize boiler size and wood consumption,

the suitability of the engine for condensing discharge, and proximity of the supplier for follow-up, the uniflow engine from Skinner Engine appears to be the most suitable engine choice. Because of the stronger position of the Canadian dollar to the Deutschmark than to the US dollar, the present cost of the Skinner engine is higher than the cost of the Spillingwerk engine.

Although a Skinner engine was used as the basis for design of the plant, there would be essentially no design changes required if a Spillingwerk engine was used. The much higher consumption of cylinder lubricating oil in the Spillingwerk engine is a significant concern since this would create an oil disposal problem and increase the possibility that oil contaminating the condensate return would cause foaming in the boiler.

The capital cost section of this Chapter indicates costs of all parts of the power plant, including the steam engine and generator. Skinner Engine supplied cost data for the steam engine and generator assuming that a Canadian supplier would be used for the shaft-speed increaser and generator and that the balance of this part of the plant, primarily the engine, would be from suppliers in the United States.

For future reference, the information supplied by Skinner Engine Co. and Spillingwerk is presented in Appendix II.

The engine/generator package chosen for the plant consists of inlet and outlet steam separators, engine, generator, skid-mounting and controls. This equipment is normally assembled on a skid at the factory and pre-tested. The inlet steam separator removes entrained water droplets that may be carried over from the boiler or formed in transit to the engine. This separator is placed immediately upstream of the steam engine to prevent damage from water hammer. A two-stage, self-draining separator with no moving parts was chosen for this application.

From the separator the steam flows to the steam engine. The steam engine is of uniflow design and referred to as the Universal Unaflow Model RV-1. This unit has a rated continuous output of 175 kW at 450 rpm and is claimed to have near infinite turndown. The steam requirement, based on mechanical shaft power, is 12.1 kg/kW_mh. Adjusting for inefficiency of the speed increaser and generator, the steam rate becomes 13.5 kg/kWh. This means a steam-flow of 2,366 kg/h is required for an output of 175 kW. At the rated steam output of the boiler the engine output would be 186 kW. Steam rates for the engine at half and three-quarter load are 13.4 and 13.1, respectively.

The Model RV-1 engine sized for continuous output of 175 kW (197 kW_m) has one cylinder having a bore of 329 mm and a stroke of 305 mm. The inlet and discharge of steam is controlled by a poppet valve driven by a camshaft. The engine speed is controlled at 450 rpm with a mechanical governor. Lubricating oil, such as

Mobil 600-Weight oil, must be injected with inlet steam to a concentration of 12 ppm by weight (oil/water). A heavy-duty oil is used for crankcase lubrication. This oil, amounting to about 95L, must be changed approximately very six months.

To raise the shaft speed to 1800 rpm for connection to the generator an inline 4.125 : 1 parallel speed increaser is used. The efficiency of this gear unit is 97%.

The speed increaser is connected through a coupling to a 1800 rpm synchronous alternator producing three-phase power at 60 Hz and 600 volts. Output voltage is maintained with $\pm$ 1-1/2% over variations from no load to full load and inclusive of a speed variation of up to 4-1/2%. Voltage regulation is maintained at any power factor from 0.8 to 1.0. The generator is rated for 175 kW (219 KVA) output under continuous operation and 190 kW output under standby operation. The generator efficiency at full load is 91.2%.

Steam discharged from the engine contains 7.6 wt % steam condensate and most of the injected lubricating oil. The lubricating oil must be separated from this exhaust steam before it is condensed and returned to the boiler. Failure to do this will cause foaming problems in the boiler and coating of heating surfaces with an undesirable oil film. An inline two-stage separator for removal of entrained droplets has been included to separate entrained oil from the exhaust steam. This unit will remove 99% of all droplets 3 um and larger

and, thereby, keep the boiler feedwater adequately free of oil. The separator causes negligible pressure drop, is self-draining and is free of moving parts. Along with the oil, the separator will remove essentially all condensed moisture.

From the exhaust separator steam flows to the condenser for return to the boiler.

The engine generator set measures 3 m high by 1.9 m wide by 3.2 m long in overall dimensions and weighs in the order of 7,000 kg.

Very little maintenance of the steam engine is needed. On a daily basis the cylinder lubricator oil level has to be checked and adjustments made as necessary to ensure proper engine lubrication is achieved. Every six months the crosshead must be adjusted, taking about one hour. At the same time, the crankcase oil must be changed, taking typically one hour. On a yearly basis it is necessary to check piston rings for wear and deposits, check the main bearing, and change the steam packing. These activities will consume about four hours and would be done at the same time as the annual boiler inspection.

4. Steam Turbine and Generator

One optional configuration considered in this study was the use of a steam turbine instead of a steam engine as the primer mover. For this analysis the boiler capacity was kept the same as used for the plant with a steam engine. The

steam turbine was sized to match the available steam supply and connected to an appropriately sized generator.

The steam flow available at the turbine is 2,366 kg/h, the same value as used for the steam engine/generator. Steam conditions at the inlet and outlet were left unchanged at 1,812 kPa, dry and saturated and 92.3 kPa, respectively.

A single-stage, bladed wheel turbine was chosen as the most suitable turbine for application at Fort Ware. The unit is robustly constructed to maximize service life under conditions that may be less than ideal. The unit is relatively simple in design and may be preassembled on a skid with the generator ready to connect to piping and electrical equipment at the site. A standard Woodward Class A governor would control turbine speed.

The turbine drives a 1,800 rpm, 600 V generator through a gear box.

At the specified steam conditions the steam rate of the turbine at full load is 16.6 kg/kWh (electric output). Consequently, the maximum output of the generator is 140 kW, considerably less than the 175 kW which can be achieved with a steam engine.

A gross power output from the generator of 140 kW would be inadequate for the community. Subtracting the power consumption of the power plant itself, the net output capacity of the plant with a turbogenerator is only 105 kW.

Comparing the steam rates for the two candidate prime movers indicates that the steam engine is 19% more efficient than the steam turbine at the specified conditions. To achieve an output of 175 kW from the steam turbine, a steam flow of 2,905 kg/h would be required. This flow could not be delivered by the boiler size chosen for analysis. A boiler sized for this steam rate would have a surface area exceeding 100 m^2 and, according to Provincial Boiler and Pressure Vessel Act, would require one Third Class engineer to act as plant chief and three Fourth Class engineers as shift workers. Such a level of training is not practical at the present time for plant personnel employed from the community. Therefore, enlargement of the boiler and use of a steam turbine at the plant is an unattractive option compared to the base case plant design.

5. Connection to Power Distribution Network

The 600-volt, three-phase power from the generator is stepped up to 2,400/4,160 V Wye for distribution through overhead lines. A simplified schematic of the distribution lines for supplying plant power and the connection to overhead lines is shown in Figure IV-10. Power is taken off at 600 V for the chipper. Plant power is supplied at 120/208 volts by a step-down transformer. The generator voltage is stepped up to the voltage required for distribution to the community.

When the 175 kW system must be shut down for planned maintenance or because of equipment failure, the existing I & NA diesel generator system may be used as a backup. Manual

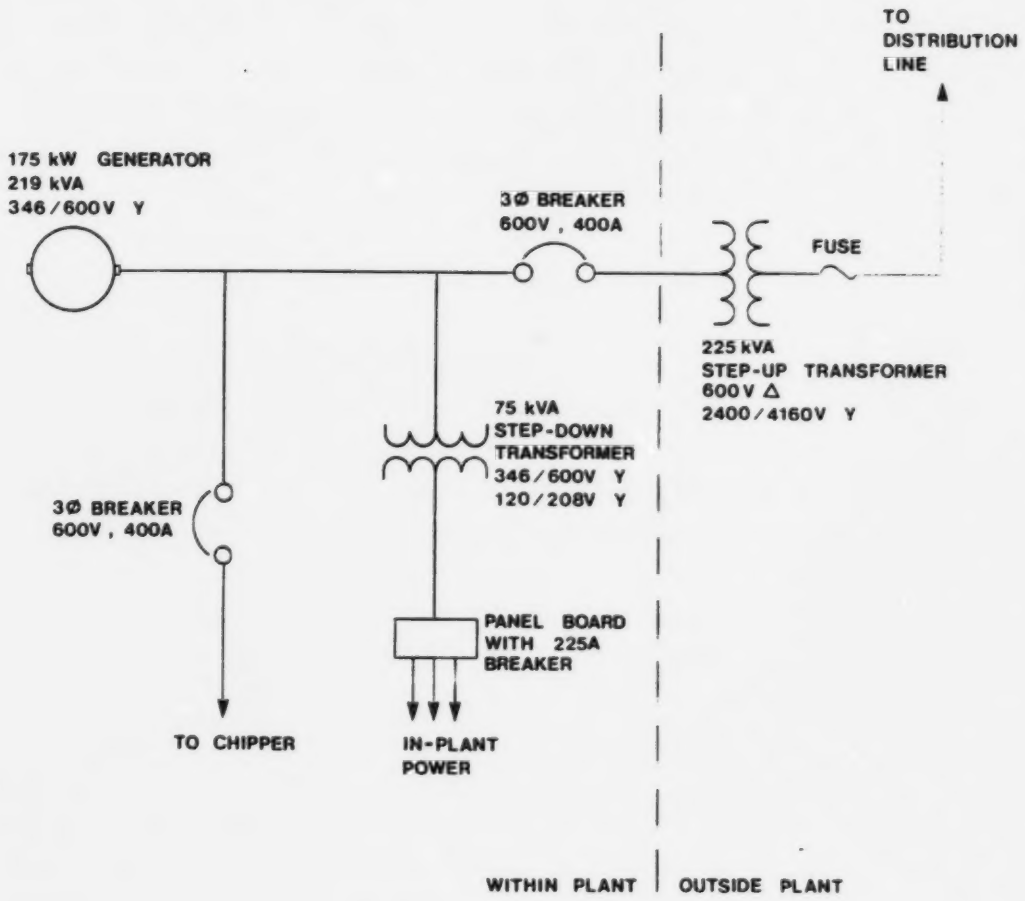


FIGURE IV-10. SIMPLIFIED SCHEMATIC OF POWER DISTRIBUTION WITHIN THE PLANT AND TO THE POWER LINES.

switches must be thrown to disconnect the wood-fired system and bring the diesel sets on line. Some loads may have to be removed from the system because of the upper limit of the output of the diesel system. Removing loads from the system is not expected to be necessary initially, but would become so once native residents have taken full advantage of the availability of electricity.

6. Waste Heat Removal and Recovery

Two cases were considered for condensing of the dry exhaust steam leaving the exhaust steam separator. This steam is at local atmospheric pressure (92.3 kPa) and a temperature of 92°C. The base case assumed no recovery of waste heat from the condenser. An optional design case allowed for recovery of sufficient heat to meet the heating requirements of the community centre and the school (1.4 GJ/h).

Figure IV-11 presents a schematic diagram for the waste heat removal section of the base case plant. In this design well water is passed through the condenser at a controlled rate, increasing the temperature of the water from 4.4°C to 38°C. Subsequent heat losses will reduce the temperature of this water stream to 35°C before discharge, this being the Provincial objective for effluent discharge to fresh water (ECO/LOG). At full generator load (175 kW), 4.95 GJ/h must be removed at the condenser requiring a water flowrate of 9.85 L/s. Under predicted average load conditions (74 kW), which allows for the daily cycle of load variation, the cooling water flowrate would be about 4.5 L/s.

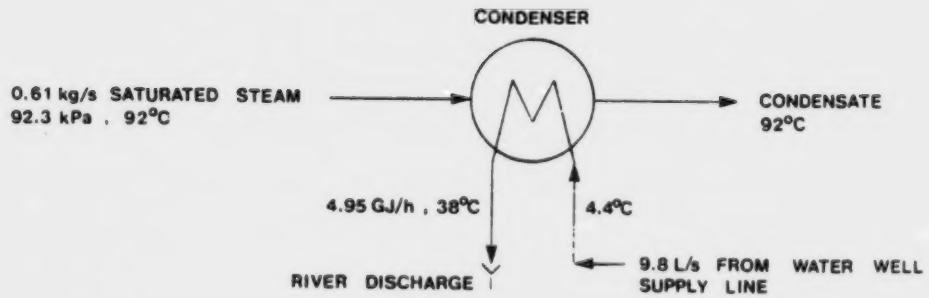


FIGURE IV-11. COOLING WATER SYSTEM FOR THE POWER PLANT AT 175 kW OUTPUT WITHOUT HEAT RECOVERY.

The cooling water for the plant would be obtained from a well at the site. As indicated by analysis presented in Section E-7 of this Chapter, the well has a high hardness, primarily from calcium, and a high bicarbonate alkalinity. At the design exit temperature for the cooling water at the condenser (38°C), the Langelier Index (Nordell, 1961) of the water is 0.9, indicating there is a significant tendency towards $CaCO_3$ scale formation on high-temperature surfaces in the condenser. Two options were investigated for prevention of scaling, these being softening of the cooling water before use, and injection of acid and/or organic compounds to reduce or prevent scaling. Both of these options were found to be prohibitively expensive, especially after inclusion of the cost of delivery of the large quantity of chemicals required.

The most practical means of maintaining effective operation of the condenser is to periodically descale the heating surfaces chemically under semi-automatic control during low-use periods. Through careful monitoring of the operating conditions in the condenser and by adjusting the cooling water flowrate to minimize the water exit temperature and, therefore, the tendency for scale deposition, it is expected that the rate of scaling could be kept to manageable levels. Descaling of the condenser may be necessary every month. The optimal frequency of this maintenance operation would have to be established by plant operators during the first year of operation and probably arranged to occur between 1200 midnight and 0600 am while operating at low waterflow conditions.

Discharged cooling water would be piped 460 m underground to the Finaly River under the pressure developed by the main water supply pump. PVC pipe of 100 mm diameter would be suitable for this duty.

At maximum continuous plant output (175 kW) and without heat recovery, 4.95 GJ/h is discharged to the Finlay River in plant cooling water. The minimum river flowrate for the period of record, which occurred in February of 1966, is 20.1 m^3/s. The bulk temperature rise experienced by the river at this level of flow with the maximum waste heat discharge from the plant is 0.016°C, well below the Provincial Guidelines of 1°C. Since ice would normally be on the river at the time of minimum flow, with a river temperature of near 0°C, and would melt on introduction of plant cooling water, the actual river temperature rise would be less than the calculated value.

Figure IV-12 presents a schematic diagram of the system for removal of heat at the condenser, recovery of part of this energy for use in the school and community centre and discharge of the balance of the energy to the river using cooling water. A 50/50 water/glycol mixture has been chosen as the heat transfer media for the recirculating condenser cooling circuit instead of well water to avoid problems associated with the high hardness of this water and to prevent freezing when the system is shut down. As explained previously for the base case plant, use of well water directly in the condenser would undoubtedly lead to scaling problems because of the high tube temperatures which would exist. Deposition of scale, principally $CaCO_3$ would necessitate periodic chemical scale removal, with attendant

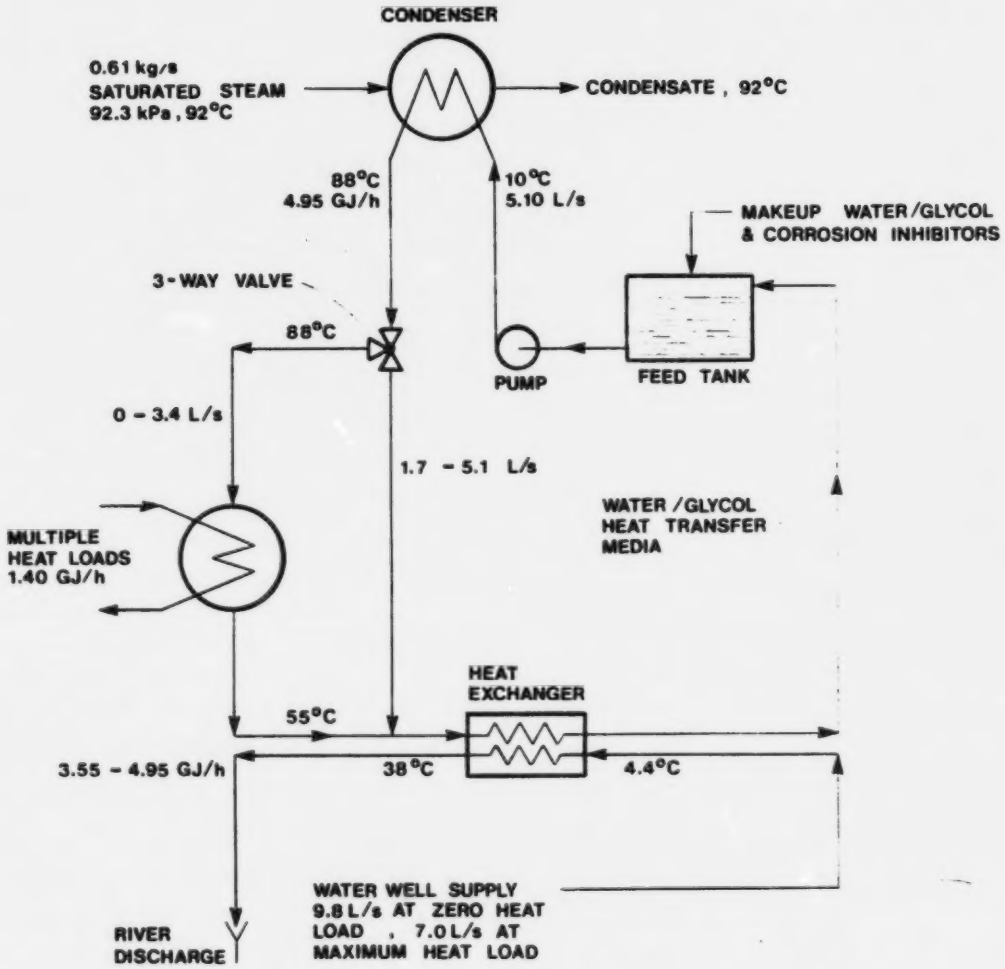


FIGURE IV-12. COOLING WATER SYSTEM FOR THE POWER PLANT AT 175 kW OUTPUT WITH HEAT RECOVERY.

down time and cost. To avoid this problem the water/glycol circuit would use softened water available as needed from the softening unit installed to treat boiler makeup water. Small amounts of makeup water/glycol and corrosion inhibitors would be added periodically to compensate for miscellaneous losses.

The water/glycol circuit would supply all the heat needed in the community centre and school for domestic hot water and space heating. The hot water produced at the plant would be circulated through a Ric-Wil® 76 mm fibreglass reinforced plastic pipe covered with an integral closed cell foam insulation and a protective fibreglass reinforced plastic jacket. This pipe measures 6 m in length by 152 mm diameter, and may be interconnected in the field using O-ring sealed connectors. Each pipe length weighs 27 kg. The supply and return legs of this circuit each measure about 275 m in length. Circulation in the circuit over this length may be achieved with a 1.1 kW pump located in the power plant.

The supply and return piping would be placed in a common trench, 2.4 m below surface and travel to a location roughly equidistant between the school and the community centre. Hot water/glycol would be brought into each building by separate secondary heating circuits, complete with a circulating pump and controls. The design of these secondary circuits was not included in this study.

Because the piping is jacketed and insulated with closed cell foam, groundwater would be kept away from the carrier pipe and heat losses would be minimized. The pipe would be anchored along its length to control thermal expansion. Such changes in pipe length are accommodated by expansion loops and the O-ring sealed connectors.

The primary circuit has been designed with an overall temperature drop of 33°C. This is a practical operating temperature drop, but greater values would advantageously reduce the flowrate and should be considered during the final design of the system.

A by-pass line has been included to allow coarse control of the flow to the heating loads and to enable isolation of the underground part of the circuit from the balance of the system

The heat remaining in the water/glycol media after passage through the by-pass and the heat recovery sections of the circuit is removed in a heat exchanger using cooling water from the supply well. As discussed for the base case design, scale would deposit in this unit and would have to be removed chemically at regular intervals. The rate of deposition could be minimized by operating at the lowest practical water exit temperature.

When generating 175 kW, 4.95 GJ/h must be removed to condense engine exhaust steam. For 78°C temperature rise of the water/glycol a flowrate of 5.4 L/s is required. Depending on the magnitude of the building heat load, flow of water/glycol through this section of the circuit will vary from 0 to 3.4 L/s. The cooling water requirement will vary depending on the amount of heat recovered for heating purposes. At full plant generator output, the cooling water requirement will vary from 7.0 L/s with the full heat load of 1.4 GJ/h, to 9.8 L/s with zero heat load. When operating at the expected average power demand 74 kW, the cooling water flowrate will be 1.8 L/s with the full 1.4 GJ/h heating load being satisfied increasing to 4.5 L/s when there is zero heating load.

7. Systems for Supply of Makeup and Cooling Water

(a) Water Supply

The demand for makup and cooling water varies with electrical load and depends on whether or not waste heat from the condenser is recovered for use. The total water requirement for various conditions of operation is as follows:

COOLING CIRCUIT DESIGN	TOTAL WATER FLOWRATE (L/s) GENERATOR OUTPUT (kW)	
	74	175
Zero Heating Load	4.53	9.86
1.4 GJ/h Heating Load	1.83	7.06

Data shown for 74 kW apply to the predicted average annual continuous generator output.

The water required for cooling and makeup would be obtained from a well located on the plant site so as not to affect the supply of water to the community. This well would intercept the same aquifer used for the community wells which are situated on the west side of the community about 100 m west of the Band store, north of the airstrip. Water table depths for these wells were 16 to 17 m, hence, the well placed at the plant will have a similar depth. A survey of the elevations of the water table and the level of the Finlay River

during aquifer tests (Thurber Consultants Ltd., 1984) indicated that the water table gradient was 0.4% between the wells and the river, suggesting the river is a discharge point for the aquifer. When this is considered in cojunction with the high capacity of the community wells, pumping at a well near the plant is not expected to affect the community supply, though a pump test at such a well would be needed prior to final design of the power plant.

The installed community wells were completed with 152 mm casings and corresponding telescoping screens placed 7.3 m and 7.8 m below the static water level. Both wells were capable of producing at a greater rate than possible with a pump that could fit through the well casing. Thurber Consultants (1984) estimated the safe yield of the well based on these test conditions to be equal to the maximum rate of submersible pumps that will fit in a 152 mm casing, or 8 L/s. They observed that "larger diameter wells of much higher capacity could be installed in the aquifer if required".

The high capacity of the aquifer makes it a practical and economical soure of supply for the power plant. The maximum demand of the power plant when generating 175 kW is 23% in excess of the pumping limit imposed by the 152 mm casing for the community wells, but could be readily produced using a 203 mm casing. This source of water is preferred over using the Finlay River with the attendant problems of freezing conditions and suspended solids. A detailed examination of the relative costs of river versus well supply was not

conducted for this study. The community water distribution system, which was also considered as a source of water, does not have sufficient capacity to supply both the community and the power plant at their maximum demand rates.

A relatively simple water supply system has been considered for the power plant. The system would consist of a well drilled to a depth of about 28 m and completed with 203 mm casing and a well screen, a submersible pump, piping, low-level well sensor and necessary controls. The pump has been nominally rated for production of 15 L/s at 345 kPa (gauge), requiring connected power of 11 kW_m. All surface equipment for operation of the well is located in the boiler plant.

In the case of failure of the water supply pump, steps would be needed to allow for the effects of loss of makeup and cooling water. Loss of makeup cannot be tolerated for a prolonged period so that equipment is included in the plant for emergency supply of this water from the community water system. The amount of water possibly required for this purpose would be very small. In the case of loss of cooling water, the boiler would have to be shut down and any steam produced while the boiler is cooling down would be vented.

Potable water needed at the plant for washroom facilities will be obtained from the community water system.

Water produced at the power plant well is expected to have the same composition as measured at the two community wells. Analysis of samples from these wells (Table IV-1) indicates the water has a very high hardness, due primarily to calcium bicarbonate, and is alkaline. Additional water quality data were reported by Aquaterre Consultants Inc. in November 1982 for the water well northeast of the school. This well was drilled to a depth of only 7.9 m and had a static water depth of 4.3 m. Although clearly much shallower than the community wells, it had similar hardness (234 mg/L), calcium content (74 mg/L), magnesium content (12 mg/L) and bicarbonate content (202 mg/L). Consequently, water produced from a well at the power plant is expcted to have a similar alkalinity (203 mg/L).

(b) Makeup Water

Makeup water is required for the boiler to replace water discharged as blowdown directly from the boiler and removed with lubricating oil by the exhaust steam separator. The amount of blowdown depends on the quality of the makeup water, type of water treatment and preferances of the boiler operator. A realistic level of blowdown is 2% of the steam production rate, or 47 kg/h at 175 kW output, on a continuous basis. The amount of water removed from the system by the exhaust steam separator is 180 kg/h when operating at 175 kW output. Therefore, the makeup water requirement amounts to 227 kg/h on a continuous basis when operating at rated capacity. The amount of makeup water required at part load will depend on the system efficiency, but as a first-order approximation will vary linearly with output.

TABLE IV-1

ANALYSIS OF WATER FROM THE TWO DEEP COMMUNITY WATER WELLS AT FORT WARE

PARAMETER		COMMUNITY WELLS	
		TH84-1 4-17-84	TH84-2 4-20-84
Physical Parameters			
pH		7.96	7.87
Specific conductance	(umhos/cm)	390.00	371.00
Colour	(CU)	--	--
Turbidity	(JTU)	--	--
Suspended Solids	(mg/l)	--	--
Dissolved Solids	(mg/l)	--	--
Total Hardness	(mg/l)	232.00	227.00
Dissolved Anions (mg/l)			
Bicarbonate	HCO_3	190.00	146.00
Carbonate	CO_3	Nil	Nil
Chloride	Cl	L0.50	L0.50
Sulfate	SO_4	35.00	18.30
Fluoride	F	0.13	0.12
Nitrate + Nitrite	N	0.078	0.077
Phosphate	P	--	--
Silicate	SiO_2	3.40	3.00
Total Organic Carbon		9.50	3.80
Dissolved Metals (mg/L)			
Calcium	Ca	62.00	61.00
Magnesium	Mg	18.70	18.10
Sodium	Na	2.21	2.53
Potassium	K	1.40	1.50
Cadmium	Cd	--	--
Copper	Cu	--	--
Lead	Pb	--	--
Zinc	Zn	--	--
Iron	Fe	L0.03	L0.03
Manganese	Mn	L0.005	L0.005
Total Metals (mg/l)			
Iron	Fe	L0.03	L0.03
Manganese	Mn	L0.005	L0.005
Coliform			
Presumptive		2.00	2.00
Confirmed		L0.00	L0.00
Fecal		L0.00	L0.00

L = less than; mg/l - milligrams/litre
Source: Thurber Consultants Ltd., 1984

Because of the high calcium and magnesium content of the well water that would supply the plant, water treatment is necessary to prevent severe scaling and associated operating problems and costs. A cation exchanger with regeneration capability has been chosen for this service. This unit uses a gel-type cation exchange resin that is regenerated periodically under automatic control with brine from an attached brine tank. The control system incorporates a manually set timer which controls the automatic regeneration cycle. Operation of the unit is extremely simple, requiring only addition of salt to the brine tank at regular intervals and routine inspection to ensure the unit is operating normally. The cation exchanger has been sized for a water flowrate of 320 kg/h and for removal of all calcium and magnesium at the observed concentrations. The cation exchanger is supplied preassembled with tanks and control ready for electrical connection and plumbing.

Based on the water analysis the alkalinity of the feed water does not require adjustment on a continuous basis. The total alkalinity of the makeup water is at an acceptable level for the boiler pressure used, and is near the preferred level of 250 ppm as $CaCO_3$.

Internal treatment of boiler water is needed to maintain the desired water quality. Sodium sulphite must be added to remove oxygen and, phosphate and caustic must be added to maintain the pH of the water at about 10.5. Phosphate will normally be maintained at an

excess concentration of 40 ppm in the boiler to precipitate out any hardness reaching the boiler. These chemicals will be added by the boiler operator based on routine tests of the boiler water. This activity is a normal part of the boiler operator's training. A corrosion inhibitor would also be added in small quantities as part of the internal treatment program.

A feeder system has been included for direct injection and metering of boiler chemicals to the feedwater. This equipment is very simple in design, consisting of a metering pump with adjustment control and a solution tank. During normal operation, the required mixture of chemicals would be regularly added to the solution tank. After startup of the boiler frequent tests of the boiler water by the boiler operators would be needed to determine the required injection rate of chemicals for internal treatment. The optimum proportions and rate of injection of the chemicals would be ascertained over a period of time as data are gathered on the water composition. Following this period of adjustment, operation of the chemical injection equipment would become routine and the rate of injection of chemicals would stabilize. Normally the supplier of water treatment chemicals will assist the user in determining the mixture of chemicals needed to protect the boiler and will supply this mixture in bulk form.

The power consumption of the equipment for external and internal water treatment is negligible.

(c) Cooling Water

For the base case plant, cooling water is required at a variable rate depending on the plant output, reaching 9.8 L/s at 175 kW output. Allowance must be made for generating in excess of the rated plant capacity, perhaps at outputs up to 186-190 kW. At the highest output, the water requirement is 10.6 L/s. The water supply system has been sized to deliver at rates in excess of this consumption level.

Cooling water for the condenser is drawn from the plant water supply. Based on recorded data for the community wells, the cooling water will be delivered to the condenser at near 4.4°C. The water is heated to 38°C on passage through the tube-side of the condenser, then allowed to cool during transit to the Finlay River for discharge at about 35°C.

For the base case plant, cooling water passes directly from the condenser to the river. In the alternate design, heat is recovered from the cooling water by the water/glycol circuit then the remaining heat is removed by the cooling water for discharge to the river.

Cooling water is supplied at the pressure developed by the main well supply pump. This pressure is sufficient to achieve the required flow through the tube-side of the condenser on the shell-side of the heat exchanger, depending on the plant design, and through the discharge line to the river. The flow of cooling water is controlled automatically using temperature feedback from the exiting cooled-water stream.

8. Power Plant Building

A building having a floor area of 84 m^2 and an interior height of 6 m is needed to house the boiler, steam engine, generator, controls, etc. as well as a small office and washroom for the plant personnel. This building would be insulated and be complete with heating and lighting systems, work bench with tools and a clear work area for disassembling equipment. The floor of this main part of the plant would measure about 8.5 m x 10 m.

A separate area attached to the main plant would house the chipper and feed conveyor. The wall separating the chipper area from the plant proper would be made of sound absorbant material to reduce noise levels in the plant during the chipping operation. A floor area of 4.5 m x 4.5 m has been allowed for this work area. The wall facing the storage yard would be open to allow workers to transfer fuel from the tractor to the vibrating conveyor. The two exposed walls of this chipper room would be of relatively light construction but contain sound absorbant materials.

The storage bin would be located outside adjacent to the north side of the main plant building. No problems with freezing of the fuel chips into chunks will be encountered because of their low moisture content.

Pollution control equipment, blower and discharge stack are located outside adjacent to the east wall of the main building.

The main distribution transformer is located away from the power plant in a 9.1 m^2 fenced area. This site is close to the tentative location of the roadway by the plant.

Open area near the plant has been allowed for storage and maintenance of plant equipment.

F. Energy and Material Balance

1. Power Output of Plant

(a) Steam Engine Based Plant (Base Case)

Power will be consumed by the community and by the power plant itself.

The community as a whole is expected to have a peak demand ultimately of 176 kW (including the community centre) and an annual consumption of 455,000 kWh.

Operation of the chipper and the conveying equipment to transport the chips to the storage bin has a high power demand for periods when chipping is occurring. Because the peak demand of this part of the feed system may reach 80 kW for very short periods of time, with logs of the maximum size, chipping must be done at off-peak times. Sufficient capacity has been allowed in the fuel processing equipment so that enough fuel may be easily chipped during daylight off-peak hours. The actual power consumption of the chipper is typically 6 kWh/tonne of as-chipped hardwood at 20%

moisture content (Simons and Levelton, 1983). Therefore, the average demand during chipping at the typical maximum chipping rate that could be achieved with the equipment (3.8 ODt/h) is 29 kW. The annual consumption of power by the chipper is estimated to be 13,000 kWh.

Power is also consumed by the boiler, bin unloader, feed conveyor to the boiler, metering bin and the water supply pump. The connected power demand for this equipment is about 50 kW. This full demand will occur only when operating at somewhat in excess of the rated plant capacity. The annual average demand of this equipment is expected to be 20 kW, leading to annual power consumption of 175,000 kWh.

The annual consumption of parts of the plant has been estimated to be as follows:

Community	455,000 kWh
Fuel Preparation Equipment	13,000 kWh
Bin unloading and balance of plant	175,000 kWh
	643,000

The power available for plant and community use at rated plant output is estimated to be as follows:

Boiler plant (excluding chipping)	35 kW	
Community	140 kW	(balance)
	175 kW	

With the boiler operating at its rated steam output the plant could generate up to 185 kW, which would raise the power delivered to the community perhaps to 145 kW. Operation of the boiler at 10% in excess of its rated capacity would increase output to the community to 165 kW.

If after growth in power demand in the community the peak demand reaches the estimated 176 kW, the power plant will not be able to satisfy the existing demand. This will not be a problem initially, but the demand for power must be monitored on a regular basis to gauge when such a system overload may arise and to take the necessary corrective action.

Two options exist for increasing the availability of power in the community. The first is expansion of the wood-fired plant by addition of another boiler and other equipment to increase the plant capacity to perhaps 300 kW. The second option is to utilize the existing diesel electric generators operated by I & NA to synchronously cogenerate power during times of peak demand. Use of the diesel electric generators to cover peak demand is the most attractive of the two options because such an approach allows for operation of the wood-fired system at a high utilization factor and as a base-load unit, as well as making good use of the existing diesel system. Wood-fired plants are better suited to base-load operations than peak-load operation because of their slower response to load changes and their high cost of installed capacity compared to diesel-fired plants. With suitable control equipment the diesel

power plant could be automatically brought on-line and synchronized with the output from the wood-fired plant according to demand on the system. This approach would also allow the diesel power system to function as a partial backup power plant allowing for routine and emergency shut down of the wood-fired plant. Since the actual electricity consumption during times of peak load is small compared to that during base-load, wood would remain the predominant fuel.

Before any steps are taken to expand the capacity of the plant or tie-in the diesel electric generators for peak loads, every effort must be made to moderate power demand. A monitoring program would be needed to support this effort and supply the data needed to confidently reschedule demand as much as possible to avoid overloading the power plant at peak-load times. Obvious steps that could be taken include:

- avoiding use of the school during peak residential demand occurring between 5:00 and 7:00 pm;
- avoiding use of the community centre during peak residential demand;
- discouraging use of electric heaters in residences;
- limiting peak demand by residences to 2 kW.

These steps could all be implemented through voluntary action with only minor inconvenience to the members of the community. Implementing all measures would reduce peak demand to a level comfortably below 145 kW.

(b) Steam Turbine Based Plant

The steam turbine base plant has a capacity limit of 140 kW. The power plant at full load requires approximately 35 kW for operation of all equipment, excluding the chipper and associated conveyors. The net power available for the community is 105 kW, a value considerably below the estimated community peak demand of 175 kW. From this it is evident that the steam turbine based plant is not a viable alternative for Fort Ware.

For comparison purposes, an economic analysis has been done for the steam turbine based plant. To this end, estimates were made of the annual power output of the plant. The annual power consumption figures used for the economic analysis are as follows:

Community	361,900 kWh
Power Plant	188,000 kWh
	549,900 kWh

2. Energy Balance

Figure IV-13 presents a Sankey diagram showing energy balance for the base case plant when operating with a plant output of 175 kW. The boiler efficiency at this load level is 74%. The steam engine and generator convert 11% of the avilable energy in the steam to electricity, resulting in an overall plant efficiency of 8.2%. The net plant efficiency after allowance for plant demand of about 35 kW, is 6.6%.

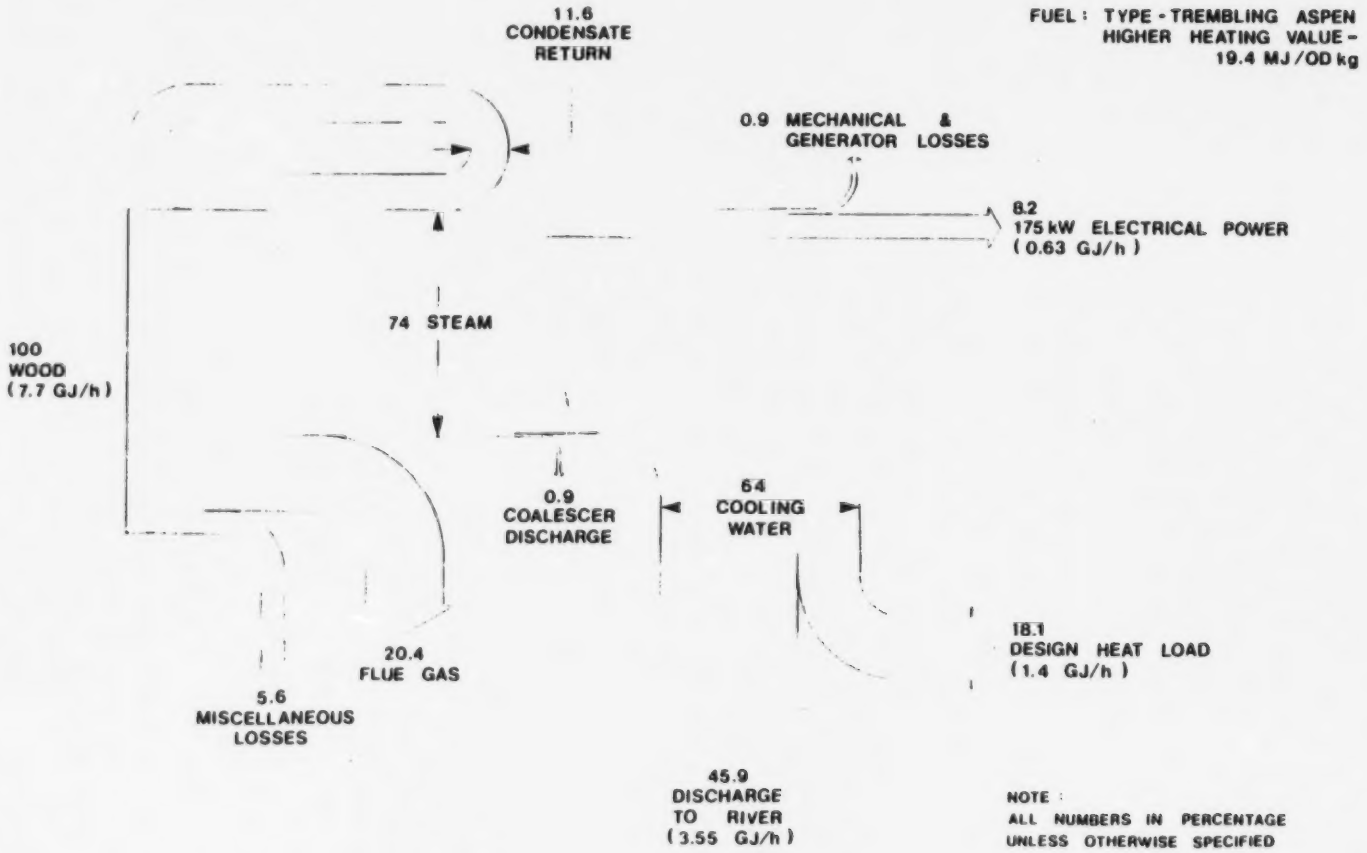


FIGURE IV-13. ENERGY BALANCE FOR THE POWER PLANT AT 175 kW OUTPUT.

For the base case plant, 64% of the energy in the wood fuel is discarded to the river in the cooling water.

Use of the optional water/glycol circuit enables recovery of part of the energy would otherwise be discarded. At the design heat load of 1.4 GJ/h, the heat recovery system captures 18.1% of the wood energy, or 28% of the total waste heat, for use in the community centre and the school. The overall plant efficiency in this case is 26.3%. Ideally, the plant efficiency could reach 49% if all waste thermal energy available above 38°C is recovered.

Operating at an expected annual average load of 74 kW, the overall plant efficiency reduces to 7%. At this load, the boiler has a 70% efficiency. The steam engine/generator captures 10% of the available energy in the produced steam.

The overall efficiency at full load of the steam turbine based plant is 6.6%, somewhat less than the value for the base case plant because of the lower efficiency of the turbine. The annual average efficiency of the plant would be less than this figure, perhaps near 5.6% after allowance for part-load performance of both the boiler and the steam turbine.

3. Material Balance

Figure IV-14 presents results for a mateial balance of the base case power plant when producing at its rated output of 175 kW. Wood is consumed at a rate of 400 OD kg/h, bringing with it water at a rate of 100 kg/h. Ash in the wood at a level of 0.3 wt %, dry basis, is produced as a residue in the grate of the boiler and as a discharge from

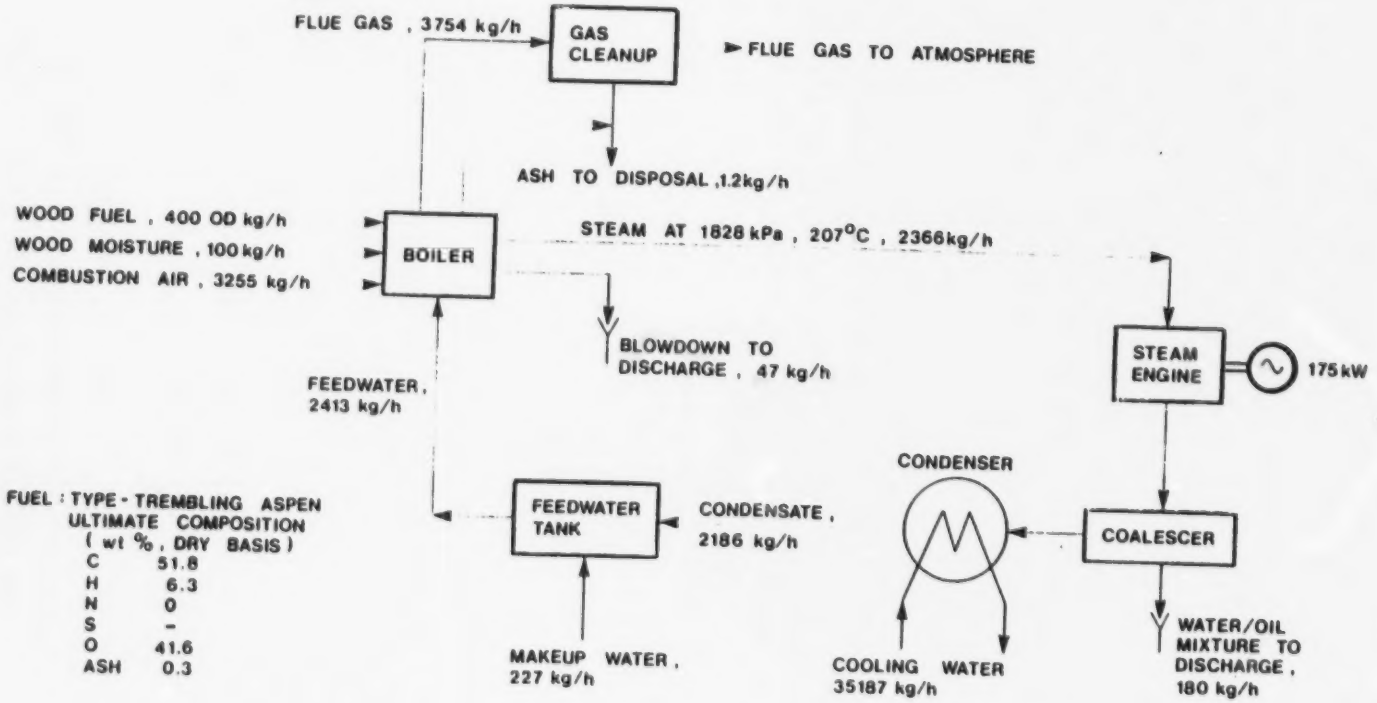


FIGURE IV-14. MATERIAL BALANCE FOR THE POWER PLANT AT 175 kW OUTPUT.

the air pollution control equipment at a rate of 1.2 kg/h. This ash would have to be discarded at regular intervals in a separate landfill site or returned to the forest for its nutrient value. A water stream contaminated with lubricating oil to a concentration of 156 ppm is produced at a rate of 180 kg/h. Blowdown containing sludge from the boiler is produced at an estimated rate of 47 kg/h, on average. Blowdown will depend on boiler operation and be adjusted based on results from day-to-day monitoring of water quality.

The material balance shown in Figure IV-13 applies when the plant is operating at its rated output. The wood consumption rate at this level of output is 2.29 OD kg/kWh. At the expected annual average output of the plant the wood consumption rate is 2.65 OD kg/kWh, higher than the above value because of lower overall efficiency of the plant.

The estimated annual power consumption for the community and power plant is:

Community	455,000 kWh
Power Plant	188,000 kWh
	643,000 kWh

This is equivalent to an average demand of 74 kW continuously throughout the year.

At the average consumption rate of 2.65 OD kg/kWh, the annual wood requirement is 1,700 OD tonnes (1,700 cords). The initial wood consumption rate is expected to be perhaps

1,000 OD tonnes (1,000 cords) because of the initially low consumption of power by the community resulting from a lack of electrical appliances.

The estimated annual average efficiency of the steam turbine based plant is 5.6%. The corresponding value for the annual consumption of wood is 3.3 OD kg/kWh per year. 1,815 cords per year would be consumed.

G. Plan for Plant Construction and Shipment of Supplies

1. Equipment Shipment

The remoteness of Fort Ware and the lack of access by land presents several difficulties to shipment of equipment and materials for construction of the plant. The cost of shipment of these supplies has a substantial impact on the total cost of the project. Shipment of the boiler, furnace and steam engine is particularly difficult and costly because of their weight.

The weight and size of the boiler equipment prohibits assembly into packaged modules that could be quickly interconnected and supplied with utilities at the site. The sizes and weights of the major components of the boiler system have been itemized previously in Section E-2. The heaviest components and, therefore, the most difficult to ship are the boiler proper (8,170 kg) and the combustion chamber (10,890 kg).

Another heavy and bulky piece of equipment is the steam engine/generator set which weighs in the order of 7,000 kg.

Several potential means of transporting equipment and materials to Fort Ware were investigated. These included (1) air transport from Ingenika preceded by barge shipment from Mackenzie; (2) air transport from Ingenika to the abandoned airfield at the mine site on the Finlay River about 24 km downstream of Fort Ware similar to case (1) above, followed by overland transport to Fort Ware; (3) barge transport to the mouth of the Finlay River followed by shipment up the river to Fort Ware and (4) helicopter transport from the barge at the mouth of the Finlay River to Fort Ware.

For all equipment and materials having a size less than 2.1 m x 1.8 m x 9.1 m and a weight less than 3,600 kg, the preferred means of transport is barge from Mackenzie to Ingenika and DC3 or equivalent to Fort Ware. A preferable aircraft as far as carrying capacity is concerned would be a Hercules, except such a craft cannot land at Fort Ware because the airstrip is inadequate in width and length; the minimum strip size is 46 m wide x 1,500 m long. A Hercules could operate out of Ingenika. Use of a Hercules to bring equipment to the mine site airstrip, which is of sufficient size, is impractical because the surface of the airstrip would first have to be restored and a roadway with bridges (possibly ice-bridges) would have to be built.

The boiler, furnace and steam engine are very difficult to ship to Fort Ware because of the lack of a suitable landing strip. The only means of shipment which appears

viable at present is barging to the mouth of the Finlay River and shipment up the river. Shipment up river would be possible during mid-summer using a riverboat. An existing riverboat can reportedly carry up to about 11,300 kg. This means that the boiler, furnace and steam engine would have to be shipped up river separately. Unloading of the riverboats would be difficult and require facilities built specifically for this purpose. The barge is capable of carrying somewhat in excess of 300 t on a deck area measuring 12 m x 30 m. Consequently, all of the equipment associated with the boiler (36.3 t), the steam engine/generator set (7 t) and other supplies could be transported on one barge trip. The payload on the barge is usually limited by deck area not weight.

The barge has been used to carry most supplies to Ingenika for air shipment to Fort Ware during previous construction projects. Barge shipment from Mackenzie costs about $11,000 per trip including the time for unloading and loading. The round trip itself takes about 36 hours. The cost and time for shipment to the mouth of the Finlay River would be somewhat higher.

Ords Construction Ltd. (Mr. P. Heal, 1984) has experienced costs of about $0.88/kg for barge shipment to Ingenika and air shipment to Fort Ware during construction projects in 1984. This cost factor has been used as a basis for estimating the cost of shipment of equipment and materials to Fort Ware. Greater cost could be encountered if access to the mouth of the Finlay River is blocked by floating logs, a not infrequent occurrence, and riverboat travel is hampered by poor river water conditions and the presence of sandbars.

2. Considerations for Plant Construction

Design and construction of the plant would take about ten months. The design stage and selection of equipment suppliers would last approximately three months. Manufacturing time for the steam engine/generator set is approximately seven months, and for the boiler package, approximately six months. Orders for this equipment must be made early in the design process to achieve delivery when conditions are best for shipment into Fort Ware, probably July through September.

H. Capital Costs

The installed costs of equipment and the indirect costs of engineering and construction are summarized in Table IV-2 for the base case plant. The installed costs include equipment, materials and labour for installation as well as shipment of major equipment to the Prince George-Mackenzie area by rail, duty and taxes. The costs for the power plant building and the development of the water well apply to Fort Ware or any similar community and include delivery of materials of construction.

The cost of delivery of equipment and materials to Fort Ware from Mackenzie was estimated using their total weight and a shipment cost of $0.88/kg. The total cost of shipments to Fort Ware would amount to $58,500 for a total weight of materials of 66.5 t. Addition of this value for the other capital costs leads to a total investment of $815,700.

Use of a steam turbine instead of a steam engine in the plant, with the balance of the equipment unchanged, leads to a

TABLE IV-2

SUMMARY OF CAPITAL COSTS FOR THE BASE CASE PLANT

DESCRIPTION	COST (1984 $)
INSTALLED COSTS:	
Site Preparation	2,000
Materials Handling and Preparation	
Farm tractor	17,300
Vibrating conveyor	4,200
Disc chipper	40,000
Screw conveyor to bin	11,800
Bin	20,700
Belt conveyor to boiler	3,500
Boiler and associated equipment	239,000
Steam engine/generator	209,000
Condenser	13,000
Electrical Distribution	24,900
Water treatment	3,000
Power plant building	40,500
Water supply system	6,200
Waste water discharge	17,600
	652,700
INDIRECT COSTS:	
Engineering (6%)	39,200
Contractors overhead and fee (10%)	65,300
	104,500
TOTAL INVESTMENT	757,200
COST PER KILOWATT	4,327

total installed cost of $530,000 and a total investment for the plant of $634,500 excluding shipment cost specific to Fort Ware. The cost of shipment of materials is not expected to change significantly from the previous value of $58,500, leading to a total investment for the plant at Fort Ware of $693,000.

Inclusion of a primary heat recovery circuit to supply heat to the school and community centre raises the total installed cost of equipment to $721,000. Adding indirect costs for engineering and contractors overhead and fee leads to a total investment of $836,400. The cost of shipment of equipment and materials to Fort Ware from Mckenzie or Prince George is about $3,800 greater than for the base case, giving a value of $62,300 for this cost. The grand total of these capital costs is $898,700.

I. Operating Costs

Operating costs arise from operating manpower, diesel fuel and supplies for mobile equipment, water treatment chemicals, general plant maintenance, insurance and miscellaneous items. The cost of fuel is excluded from consideration at this time since the cost of harvesting and delivery of fuel is calculated separately in Chapter V.

Table IV-3 presents a list of the various operating costs for the base case plant design. The major component of the operating cost is the labour for boiler operation 24 h/d and for handling and chipping fuel. The labour rate for the four boiler operators has been set at $12/h, somewhat less than the base rate of $13.45/h currently paid in the public sector to operating engineers with a Fourth Class certificate. Benefits have been

TABLE IV-3

SUMMARY OF OPERATING COSTS FOR THE

BASE CASE PLANT

DESCRIPTION	ANNUAL QUANTITY	PRICE	ANNUAL COST ($)
Operating Manpower			
Boiler Operators	4 x 2,330 h	$12/h	111,800
Fuel Yard Crew	1 x 2,080 h	$ 8/h	16,600
Tractor for In-Plant Fuel Handling			
Fuel and Lube Oil	10,600 L	$0.80/L	8,500
Maintenance			1,000
Tires (3000 h)			800
Water Treatment Chemicals			2,000
Maintenance			
Materials and Labour			7,000
Annual Boiler Inspection			1,400
Administration and General Overhead			32,100
Insurance			7,000
		TOTAL	188,200

ignored because of the low cost of living on Reserve land. Shift differentials have been included as a component of the basic wage rate. The labour rate for the one yard worker needed to recover fuel from storage and feed it to the chipper is comparable to the rate given to workers harvesting wood (Chapter V), assuming a typical productivity factor for the wood cutters. The value shown for hours worked per year by boiler operators includes the time at regular rate that would be worked as overtime by four men following a conventional 40 h-shift schedule; each man works an average of 2 h overtime each week at time and one-half and works statutory holidays at double time. The costs for the annual boiler inspection and insurance are typical values.

The operating costs for the optional plant design using a steam turbine differ slightly from those for the base case. The labour cost component is unchanged. The maintenance cost increases and the insurance cost decreases leading to a total annual operating cost of $189,000.

Addition of a heat recovery circuit increases the annual operating cost, excluding wood costs to $189,600. The labour cost for this case remains at $128,400/yr. The balance of the operating costs, $61,200, is only slightly higher than that for the base case plant.

V. WOOD FUEL HARVESTING AND MANAGEMENT

A. Introduction

A boreal forest of Lodgepole Pine, Spruce, Aspen and Cottowood surrounds the Indian community of Fort Ware, situated on the north bank of the Finlay River. In general forest components are a product of past natural disturbances, foremost of which being lightning and fire. Relative to age, all display those characteristics of natural stands and normal succession experienced in these northern climes.

Within the immediate vicinity of this community, coniferous stands may range in age from seedlings growing amongst windthrown remnants; to dense pines of small diameters, their growth stagnated by overwhelming occupancy of the site; to prime admixtures of highly competitive Lodgepole Pine and Spruce; to mature, overmature and decadent stands displaying varying degrees of decay and mortality. Similarly, the poplar species, Aspen and Cottonwood, may be found vigorously capturing a site after a fire, sheltering an understory of coniferous seedlings, or appearing as decadent remnants within a well established coniferous stand. This variety in forest age and structure has answered many needs of the native peoples in the past, moreover, can offer opportunities in the future.

Generally, the composite stands appear on favourable terrain: the valley bottom, alluvial benches and gentle mountainous slopes. Yet for lack of access, most of the forest within a 10 km radius of the settlement can only be traversed by foot. To explain - Fort Ware is situated on the southern boundary of a peninsula of land bounded by the Finlay River in the south, the Fox River in the west, the Kwadacha River in the east and a mountain range in the north of which Mt. Chief Davis, as per Figure V-1, is a part.

There are no bridges or good haul roads, only trails . Hence, development of the surrounding forest for a major fuel supply is either limited to operations on the peninsula itself, or to the winter months when rivers are frozen over and easily crossed by heavy equipment via ice-bridges. If need be, those areas south and east along the Finlay River could be tapped as an additional source, but as mentioned earlier the Kwadacha River presents an obstacle that initially can only be surmounted during winter.

There is one other major constraint to harvesting by the Band on Crown forest land thereabouts. Fort Ware and environs are in the MacKenzie Timber Supply Area (TSA). This forest land base is dedicated to the growing of successive crops of timber for commercial manufacture. More importantly, the Crown has committed the area's annual yield to two licensees: B.C. Forest Products Ltd. and Finlay Forest Industries Ltd., both of which have wood processing complexes at MacKenzie. In other words, all coniferous crops, both present and future, have been allocated to these companies. Apart from any down, dead or fire-killed coniferous volumes that may be encountered in forest stands, only the deciduous species remain unencumbered at the present time.

A more detailed analysis of the forest resource about Fort Ware was deemed an essential, if not the prime step toward determining the viability of this project.

This settlement, however, is not unique. It is repeated numerous times across Canada. Characteristically, Band members live in isolation; have little contact with the outside world, as we know it, save by chartered aircraft; lack electric power; are heavily dependent on costly fossil fuels; and experience disturbingly high rates of unemployment. Yet all reside amongst a potential source of energy (the surrounding forest) that will more than meet their needs.

In the main, several fundamental questions are addressed in this report as the resource is considered in depth:

- Can the forest with all its constraints support such a venture?
- What will be the unit cost of wood delivered to the facility?
- What assistance will the Band require to generate and sustain the annual wood supply?
- Will the harvest complement the lifestyle of the Band, make them more self-reliant and offer other benefits which may improve their standard of living?

The following report has been designed to address these questions.

B. The Resource

In real terms, 1,700 to 2,000 hectares in this region would be capable of meeting the annual wood requirements of the proposed facility. This statement is based on growth rates experienced in natural stands and a rotation of 120 years. Under simple management practices, up to 17 hectares would be harvested and planted annually. Under more intensive forest management, the total area required could probably be reduced to 1400 hectares or an area 3.5 times that of the present Fort Ware Reserve. But such statements are academic, for as mentioned, the productivity of the unalienated Crown land about Fort Ware is fully committed to growing coniferous volumes for the manufacturing plants at MacKenzie. Presently, the deciduous trees are weed species, unwanted occupants of the forest, with no commercial value; the most obvious source of supply for the proposed facility at Fort Ware.

When approached during March, the Regional Office of the Ministry of Forests did a cursory examination of the resource and concluded that within a 20 km radius of Fort Ware there is an estimated yield of 4,430 m^3 (of deciduous volumes) annually, more than enough for the annual requirements of the proposed project.

In effect, the Ministry agreed in principle to the availability of the deciduous volumes thereabouts and disclosed how the Band could acquire authority to harvest its requirements. Apparently three options are available. An application may be submitted for one of the following tenures:

- Timber Sale Licence.
- Forest Licence.
- Woodlot Licence.

Each is a contract to harvest a definite volume annually.

1. Tenures

(a) Timber Sales Licence

The Timber Sale Licence is considered the simplest method by which to acquire the fuel wood for the proposed plant. It covers a definite area and is the least onerous to the licensee. This tenure, however, has a maximum term of 10 years. It is not renewable. Because a new licence would have to be applied for on the expiry date, 10 years hence, forest commitment may be even greater than at present and exposure to competition and risk of not acquiring a new licence becomes a distinct possibility. Application for this tenure, therefore, should be approached with caution.

(b) Forest Licence

Both the Forest Licence and Woodlot Licence are replaceable without exposure to competition.

The Forest Licence is a 20-year agreement, replaceable every 5 years for another 15 years; in other words a perpetual licence subject to performance. This licence has no bounds, may be exercised anywhere throughout the TSA, but requires cutting permit approval. Moreover, licensee obligations are much greater than the Timber Sale Licence particularly with reference to utilization standards and reforestation.

(c) Woodlot Licence

Similarly, the Woodlot Licence is a 15-year agreement, replaceable every 5 years for another 10 years. In effect, this is another perpetual licence, subject to performance. But unlike the Forest Licence, this tenure has defined boundaries and a maximum area of 400 hectares. It too, carries additional obligations, foremost of which being management of the land for successive crops of timber, sustained yield and a working plan. On the other hand, whether or not the Ministry is prepared to consider applications for woodlot licences within the MacKenzie TSA, at all, is open to conjecture. So far, no volumes have been allocated to small business or woodlot licences in the TSA. It would therefore be necessary for the Band to rationalize the need for a woodlot licence program in the first place. There are foreseeable problems with this tenure primarily because of size limit. One licence would not satisfy the annual requirement of the proposed plant unless combined with the Reserve area and perhaps two other woodlot licences. Hence, individual Band members would have to apply for separate licences in order to gain the annual volumes required. Whether or not individual Band members are prepared to assume the associated obligations remains a question.

In summary, there are pros and cons for each form of tenure. Election by the Band must relate to its long-term goals and objectives. Over and above the demand for electric power, the Band must eventually decide whether it wishes to explore the opportunities in forest management and subscribe to the disciplined involvement which will provide its members with employment.

Initially the Band would do well to entertain the Timber Sale Licence. This tenure carries the minimum commitment towards the practice of forestry whilst offering an opportunity for all to ascertain if the persuit of fuel wood is a rewarding exercise, worthy of expansion to encompass silvilcutural practices that will not only improve the forest thereabouts but provide the Band with expertise for which demand is steadily increasing.

To repeat, the Timber Sale Licence is the least onerous of all the tenures. Clauses in this agreement do not change during the life of the contract. Moreover it can be applied for and acquired in the shortest possible time.

2. Field Assessment

The on-site inspection confirmed the limitations imposed by the water courses and access routes about Fort Ware. The rivers present formidable barriers to development of stands beyond the Fort Ware "peninsular" land mass except during winter. Indeed, access is rudimentary and is confined to wagon roads which soon reduce to foot trails on leaving the Reserve area. All emanate from the east end of the air strip, the Band office, store and school, and radiate northerly and northwesterly. One parallels the Fox River; another the Kwadacha River. There is much evidence to indicate that all have been established for the harvest of residential wood supplies.

C. The Sources of Energy

Two main sources become apparent: the west bank of the Kwadacha River to the north and the east bank of the Kwadacha and Finlay River to the southeast as depicted on the map, Page 139. Both require 8 km of main haul road. In addition, the east bank requires a bridge across the Kwadacha River immediately north of its confluence with the Finlay River.

In order of priority, those stands adjacent to the Finlay River offer the best return on capital invested in access roads. However, the simpler development required of those stands to the north rule in favour of the west bank of the Kwadacha River.

In general, the terrain of the Kwadacha-Finlay River Valleys is flat to undulating. The soils are alluvial sands or outwashes. Drainage is relatively good. Clays and silt deposits are not prevalent. As a result, road construction should be easy and relatively inexpensive for the harvesting of this wood supply.

In the Kwadacha drainage, both Populus species (Aspen and Cottonwood) appear in one of two forms: as a major component of immature forest types ranging up to 50 years in age or as a minor component of mature Lodgepole Pine and Spruce types. Aspen diameters at 1.37 m above the ground (Dbh) range up to 49 cm and average about 20 cm. Cottonwood frequents the water courses, appears singly or in groves. Single trees often exceed the maximum diameters of Aspen but groves average about 20 cm.

1. Deciduous Volumes in Mature Stands

Table V-1 shows an estimate of the accessible deciduous volumes available by source within a radius of 8 km of Fort Ware.

The Kwadacha West will yield an estimated a 5.7 year supply for the proposed plant; the Kwadacha East and Finlay an 11.5 year supply.

Figure V-I The Resource Sites.

TABLE V-1

ESTIMATED DECIDUOUS VOLUMES BY SOURCE[1]
(EXPRESSED IN CUBIC METERS)

FOREST TYPE[2]		KWADACHA WEST	FOX	KWADACHA EAST AND FINLAY R.
Pl S	731M	793	-	-
Pl S(A)	731M	3,030	736	-
Pl A	731M	11,921	-	-
Pl A	532M	6,145	-	-
S(A)	741G	-	-	1,953
S A Pl	741G	-	-	33,725
S A (Pl)	731M	-	-	6,173
S(Cot)	841G	-	-	2,463
Total		21,889	736	44,314

1 Data Source - B. C. Forest Service Finlay Unit Survey, 1972, Map Area and Volume Statements.

2 For explanation of Forest types see Appendix V.

2. Immature Deciduous Volumes

The provincial Ministry of Forests' records do not disclose volumes for immature stands 80 years of age and younger. Within the 8 km radius and in addition to the above volumes, the Kwadacha supports 300 hectares of immature Aspen; the Fox, 1,350 hectares. Subject to an inventory, this could amount to an additional supply of 21,000 cubic metres in the Kwadacha and 94,000 cubic metres in the Fox which represents 5.5 years and 24 years of additional supply respectively. In total the supply available on the penninsular land mass, Kwadacha East and Finlay could approach 46.7 years - all within an eight kilometer radius of the plant site.

D. The Harvesting and Management Plan

1. The Design

The plan was designed to attain the following objectives:

- Delivery of annual plant requirements at the lowest possible cost over the long term.
- Operations compatible with the abilities of the Band members.
- Complementary work and new expertise to encourage self-reliance and improve standards of living.
- Maximum employment for Band members.
- An attractive wage rate.
- Minimum initial capital outlays for equipment and road construction.
- Training of Band members in forest harvesting and management skills and practices which can lead to alternate employment off the reserve.

2. The Plan

The objectives favour development of the Kwadacha West initially. The immediate need for a bridge is eliminated; the expertise of the Band members is not challenged. Access development is simplified; capital costs are held to the minimum. All considered, the aim is for reliability at minimum cost and the provision of sufficient lead time for the wood to dry. Sophisticated logging equipment will not be required as only equipment presently owned or operated by Band members will be used. (Hence the approach will be cost effective, reliable and compatible with labour and equipment readily at hand.)

3. The Suggested Harvesting Plan

To meet the prime objective - delivery of annual plant requirements at the lowest possible cost over the long term - it is suggested that harvesting commence in mature stands where minor volumes of Aspen, Cottonwood and Birch exist. Felling, bucking, decking on "skid" trails, and extraction by tractor is a simple exercise to learn and implement. Constraints to harvesting will be minimal. Except for the selective cutting, the process emulates most logging in the interior of the province of which numerous Band members are familiar. Furthermore, although scattered throughout the stand, the individual deciduous trees are reasonably large and will yield up to a third of a cord per tree. Similarily, the flat to undulating terrain and the soils encountered are ideal for the process. Besides, this procedure introduces Band members to basic silviculture and the first step towards intensive forest management.

4. Harvesting Constraints

Every licence awarded by the Ministry of Forests incorporates performance clauses to ensure that the standards of utilization are met, that the site and residuals are protected, and that the fire hazard will be reduced to acceptable levels in the shortest time possible.

In this case, where a licence may be granted for the harvest of deciduous volumes within a coniferous stand, there is no doubt that clauses will be included in the contract to:

- limit damage to the coniferous residuals;
- limit compaction on the "skid" trails by establishing the time of harvest, i.e. perhaps summer or winter only;
- promote decay by lopping and scattering slash and logging debris;
- limit the number of "skid" trails by stating the minimum distance between trails;
- govern the location, survey and alignment of the main access routes - moreover its width of right-of-way; and
- establish utilization standards by stating the maximum acceptable stump height and minimum top diameter.

5. Equipment Available for Harvesting

The present equipment inventory at Fort Ware is as follows:

- 1 Case 850B Tractor complete with integral arch and hydraulic blade, Serial No. 7400106.
- 1 Case 580D Front-End Loader with a backhoe attachment, Serial No. 9062078.
- 1 Massey Ferguson 245 Tractor.
- 1 John Deere 450 Front-End Loader with a backhoe attachment, Serial No. 9A3T74-78.
- 1 three-ton wagon.

6. The Recommended Method of Development and Harvesting

First and foremost, the objective of lowest unit cost delivered to the plant over the long term requires that the average haul distance to the plant remain static. This can only be attained by developing access to the central point of the supply area and, as cutting proceeds, balancing more distant operations with those closer to the plant site. In this case, it therefore becomes necessary to survey and build the main haul route to "Kilometre 4" during the first year. Fortunately, right-of-way felling and clearing to a width of 10 metres will generate up to thirty percent of the plant's annual requirements and will offer the first test to the Band's ability to perform.

Subsequently, harvesting will proceed in adjoining stands so that the average haul distance remains at 4 kilometres. The main haul route will be extended as the demand to access more distant volumes arises. The cost of building the haul route is not expected to exceed $6,000 per kilometre.

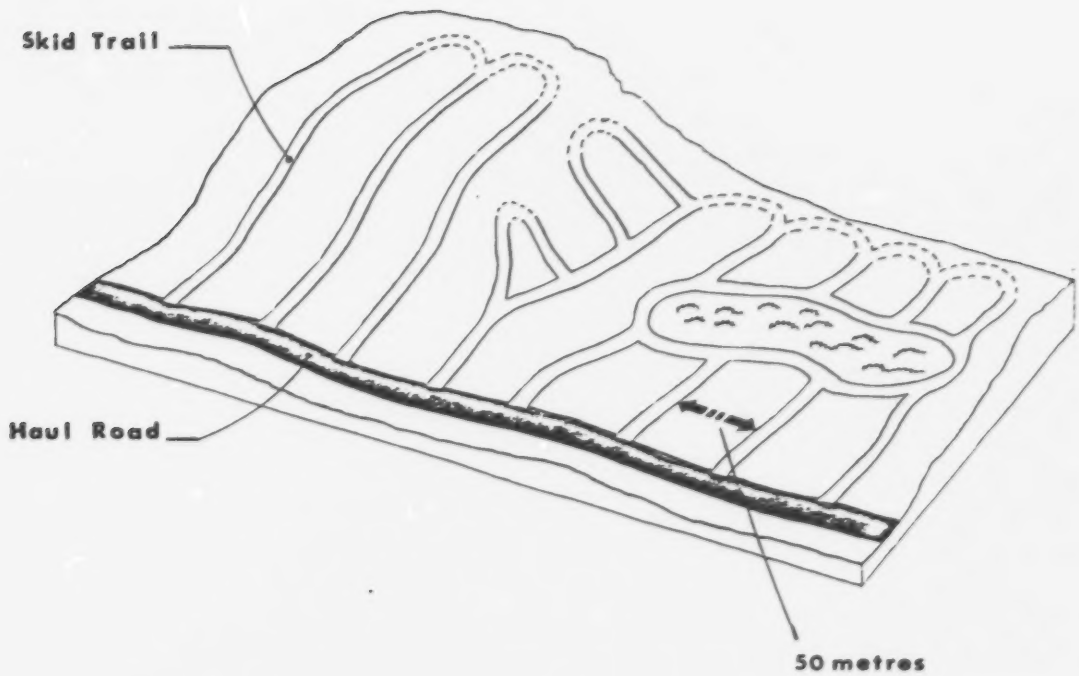
Simply put, the Case 850B is recommended for main haul road construction; the Massey Ferguson 245 Tractor for wood extraction to roadside, loading onto a wagon, and transport to the plant site. Purchase of the following equipment is also recommended: a second Massey Ferguson 245 Tractor ($16,200), two 10-ton wagons with appropriate super structure ($6,000) and two rear forklift attachments for the tractors ($3,000)

From the beginning, forest stands in the Kwadacha West will be sampled to establish which areas are suitable for cutting. Boundaries will be surveyed together with a system of parallel "skid" trails over the entire cutting area as per Figure V-2. Skid trails will be established 50 metres apart, at right angles to the prevailing winds and where ever possible at right angles to the main haul route, otherwise a branch road will be constructed.

Wood cutting will commence with the felling of all trees on the skid trail regardless of specie. Only the minimum number of trees will be felled so as to acquire the desired trail width (2.5 m) and good alignment. Trees will be felled along the surveyed trail and processed into 1.2 metre or 4-foot bolts. Two rails will be positioned along the trail before decking to elevate the bolts thereby aiding in their pick up and withdrawal. In turn, bolts will be piled or decked lengthwise across the trail.

Once the "skid" trails have been readied; the intervening deciduous trees will be felled towards them in such a way as to deposit as much of the bole and top onto the trail or close to it as possible. Again all trees will be processed into bolts and piled on the "skid" trails. Bolts larger than 20 centimetres or 8 inches in diameter will be split lengthwise by hand, using either an axe or wedge and sledge, in order to acquire that maximum diameter.

FIGURE V-2 AN EXAMPLE OF A TYPICAL CUTTING AREA



Much of this recommended method will be hand work. Bolts will be moved to and decked on the "skid" trail by hand. Similarily the wagon will be loaded and off-loaded by hand. One of the front-end loaders could be deployed as a loading unit but this added sophistication not only may challenge the abilities of the Band members but will also reduce labour content, require more training, require more fuel and equipment maintenance, and as a result will demand a higher daily production to off-set increased costs of operation. Furthermore, if the backhoe attachment is not suitable for loading bundles of bolts, a front-end fork attachment may be required. The additional cost is estimated at $4,500.

7. Training and Manpower

(a) Training

Apparently, some Band members attended a forestry course given by the provincial Ministry of Forests earlier this year. In the past some have left the Reserve at intervals to work on hydro line clearing projects. While other members have learned to operate the available equipment on various projects about the Reserve.

From the outset, this experience is invaluable and will no doubt contribute to the future success of this project, provided additional training is forthcoming in the following areas:

- Surveying, engineering and cutting block layout.
- Equipment maintenance and repairs.
- Power saw operations, maintenance and safety.
- Felling procedures.

Both equipment and worker should be given every opportunity to function effectively and safely with the mimimum of downtime. Because of isolation, it cannot be emphasized enough that disciplines prevailing in most industrial forest operations should be introduced here.

Initially two Band members will be required to assist the Professional Forester or Forest Technician charged with implementing the plan. "Hands on" training will commence immediately as the assistants learn to use compass, abney, chain, maps and air photos whilst sampling for the forest inventory and surveying the main haul route into the Kwadacha West.

In this regard should a Band member wish to become a forest technician, diploma courses are offered by The College of New Caledonia, The B.C. Institute of Technology and the Pacific Vocational Institute. The courses offered by the College of New Caledonia and B.C.I.T. span two years, require a Grade 12 standing for entry and cost approximately $1,000 per year plus room and board. The course offered by the Pacific Vocational Institute spans 5 months, requires a Grade 10 standing for entry and costs approximately $450 plus room and board. Regardless the "hands-on" training received on this project will provide the participants with an excellent understanding of planning and implementing a forest harvesting operation. The exposure will place them in good standing for similar employment elsewhere.

As the road survey approaches Kilometer "4", the superintendent will arrive to initiate right-of-way felling and clearing. Once again "hands-on" training will be offered; this time to the cutters on correct and safe felling procedures as well as power saw operations, maintenance and safety.

When the Case 850B tractor is deployed on road construction, the operator will receive training on operating, servicing and repairing the unit as well as good road building techniques.

Finally, when the Massey Ferguson 245 tractors, wagons and, if necessary, one of the front end loaders are placed into service instruction will be given in their proper and safe use.

(b) Manpower

Daily production for a woodcutter should average 5.7 m^3 (2.5 cords) of 1.2 meter (4-foot) bolts stacked on a "skid" trail. The porters should extract and haul an average of 22.8 m^3 (10 cords) per day to the plant site. As a result, a crew for the recommended program should consist of 7 to 8 woodcutters and 2 to 4 porters, who will be employed up to 100 days per year and at a time that will least interfere with the traditional quests of the Band members. Perhaps the period of May through September would be satisfactory.

It is suggested that all workers be paid on a piece-work basis in order to maintain production whilst having the participants earn the equivalent of $65 per day or more. Woodcutters would therefore receive $25 per cord stacked on the "skid" trail; porters would receive $12.50 per cord delivered to the plant site.

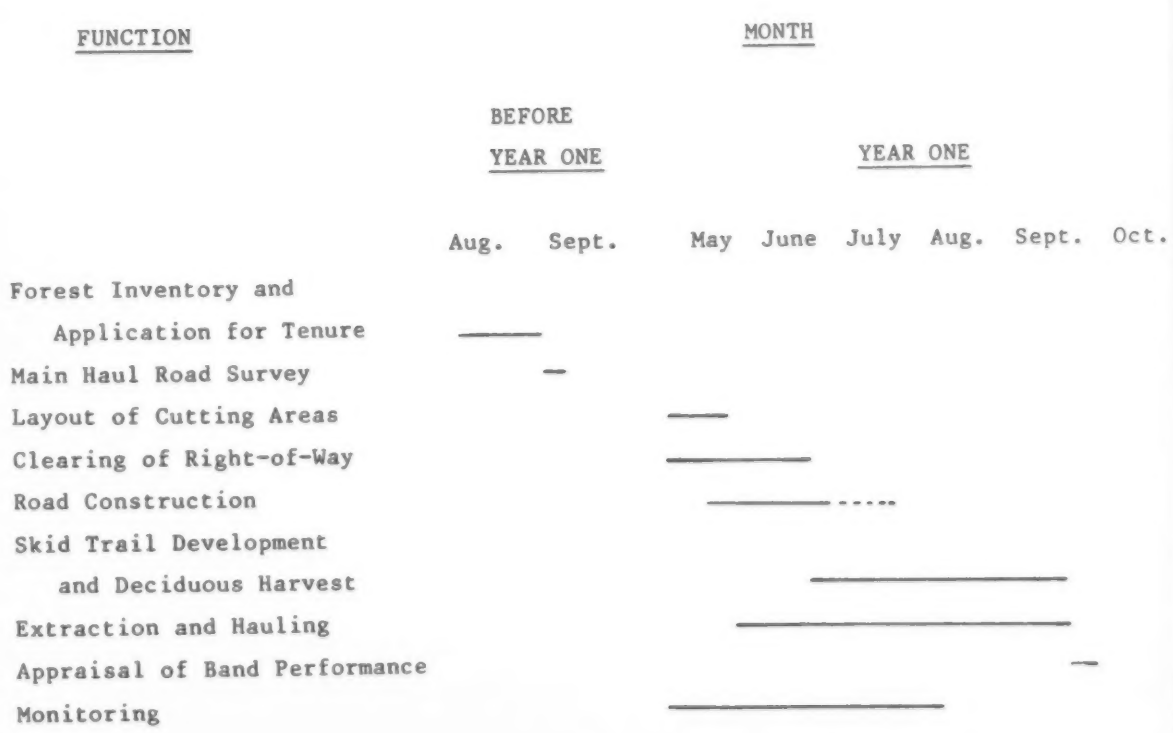
If it was deemed necessary to introduce a loading unit, then consideration should be given to increasing the number of woodcutters or having the normal woodcutting crew begin well before and independent of the porters. With a loading unit only 3 porters will be required, moreover, their piece rate will also be reduced to at least half, or $6.25 per cord delivered to the plant site, in order to off-set the cost of the loader. When the inventory of the stacked material becomes large enough to support a continuous hauling operation, the porters will commence. Both cutting and delivery should be timed to cease together.

8. Implementation Plan

As mentioned, forest operation will likely occur during the period of May through September. Ideally, all surveys should therefore be carried out during August and/or September of the year preceding the first year of forest operations to allow sufficient time for processing the application for the Timber Sale. If "time is of the essence" however, then surveys may be initiated during April of the same year but there are risks involved. Figure V-3 illustrates the timing for each function in harvesting the first year's supply.

FIGURE V-3

TIMING OF HARVEST OPERATIONS



9. Equipment Operating Costs

Appendix III(A) shows the estimated operating costs for the tractor, wagon and loading unit, if it is introduced into the program.

Table V-2 indicates the fuels and oils that may be consumed in harvesting the annual requirements for the proposed facility.

TABLE V-2

ANNUAL FUEL AND LUBRICATING OIL REQUIREMENTS

ITEM	RECOMMENDED PROGRAM LITRES	PLUS LOADER LITRES
Gasoline	3,060	3,060
Diesel	9,275	11,750
Mix oil	102	102
Chain oil	3,060	3,060
Lubricating Oil	136	136
Total volume (litres)	15,633	18,108
Approximate gallons	3,440	3,980

10. Unit Costs Delivered to the Plant Site

Subscription to the recommended labour intensive program will yield costs of $24.73 per m^3 ($56.21 per cord) delivered to the plant site. For details, see Appendix IV.

Introduction of a loader results in a lower unit cost ($20.95 per m^3 or $47.61 per cord) but also identifies the importance of higher daily delivery to the plant. Again, note Appendix IV which outlines two cases and the sensitivity of unit costs to to the volumes delivered to the plant daily. Whilst adding a loader can improve costs by 15 per cent it is noteworthy that exposure to mechanical failure is increased by 50 per cent. In effect, such an approach ignores one of the prime objectives of the program. Conversely, the porter's piece rate would have to be reduced accordingly to provide the incentive for increased deliveries to the plant.

In summary, it appears that the use of a loader should only be considered if it becomes impossible to meet deliveries within the proposed time frame.

E. Overheads

1. Supervision and Monitoring

During the first year the services of a Forester/Forest Technician and a Superintendent will be required. Initially the Forester will solicite the aid of two Band members to effect the required surveys. When the survey of the main haul route is completed, he will appoint one assistant as a working foreman responsible for clearing the right-of-way. The Band member will be trained and directed by the Superintendent. The scope of his job will gradually increase from felling and wood processing alone to part-time supervision of all aspects of the operations. He will assign areas to the wood cutters, direct the cat operator on road construction, direct the porters, and report on production. At all times, he will remain as a working foreman performing any one of the major functions as well. When the flow of wood is constant, both the Superintendent and Forester will depart, that is provided the working foreman is comfortable in his position.

It is expected that regular but brief monitoring by an outside consultant will be a requirement each year, particularly at the commencement or cessation of harvesting operations. Monitoring should take the form of a consultative session wherein the Band foreman has the opportunity to air his difficulties, explain his cost variances, mutually chart or forecast a course of operations, and receive the advice of a more experienced professional.

2. Projected Overhead Costs for the Project

As indicated, Year 1 of the project will be unique. The two consultants will be required for extended periods in order to establish an organized program and provide the required training and safety instruction.

In subsequent years, monitoring by an outside consultant is not expected to entail more than a month each year. His time will probably be allocated as follows: two weeks at the beginning of operations, one week at mid-term and one week at the conclusion of the season. And finally, there is the cost of the Band supervisor elect, the working foreman. His stipend needs to be sufficient to add stature to his position but not large enough for him to negate his responsibility as a wood cutter or porter.

Table V-3 is a summary of the anticipated overhead costs for Year 1 and subsequent years. Unit costs have been arbitrarily based on an annual production of 1,000 cords. In the final analysis, overhead costs will vary directly with the actual volumes produced annually and are therefore developed more fully in the economic analysis of this report.

TABLE V-3

PROJECT OVERHEAD COSTS

YEAR	ITEM	TOTAL	UNIT COSTS PER m3	UNIT COSTS PER CORD
1	Consultant			
	Fees	$18,000		
	Expenses	1,800		
	Superintendent			
	Fees	8,000		
	Expenses	1,000		
	Survey assistants (2)	2,600		
	Supervisor elect	3,500		
	Total	$34,900	$15.40	$34.90
After 1 Year	Consultant			
	Fees	$ 3,000		
	Expenses	500		
	Survey assistants (2)	1,300		
	Superintendent elect	3,500		
	Total	$ 8,300	$ 3.66	$ 8.30

VI. ECONOMIC ANALYSIS

An economic analysis was conducted to determine the cost of produced electricity for four plant designs:

- steam engine based plant;
- steam turbine based plant;
- steam engine based plant with heat recovery;
- diesel engine based plant.

All economic analyses were conducted using the common set of basic assumptions summarized in Table VI-1. A key assumption is the interest rate on debt. The rate used, 10%, is equivalent to a real rate of return on debt of 6% at the current rate of inflation, but less than the near 12% rate set by the Bank of Canada. For long-term financial analysis, such a rate would be excessive, especially given the low risk and long-term of the debt. Real interest rates as low as 4% are frequently used by some Crown Corporations which are able to obtain preferred rates. The procedure used to calculate the power price yields a value constant in 1984 dollars that is equivalent to the non-uniform current-dollar price over the life of the plant.

A. Steam Engine Based Plant

The power price was determined for the base case plant which incorporates a steam engine/generator. For this analysis an estimate was made of the annual power production of the plant for every year of operation. Through inspection of the expected demand at Fort Ware and consideration of the growth of power consumption at other native Indian communities, it was concluded that annual consumption would increase from 386,000 kWh in the

TABLE VI-1

ECONOMIC ASSUMPTIONS AND DEFINITIONS

Plant Construction Period:	Plant constructed in 1984 and 1985 for operation in 1985
Plant Life:	25 years
Financing:	100% debt repaid with interest in a uniform series of annual payments over the life of the plant. All debt is incurred at the start of 1985
Interest Rate on Debt:	6% real; 10% nominal
Inflation Rate:	A uniform annual inflation rate of 4% exists over the life of the plant
Timing of Costs:	All operating costs are paid at the end of the year
Cost of Power:	The cost of power in 1984 dollars was determined that yielded a net present value of revenue and costs of zero. The cost of power over the life of the plant inflates at a rate equal to the annual inflation rate
Discount Rate:	The discount rate used in the net present value analysis equals the interest rate on debt.

first year of operation to 643,000 kWh in the fourth year of operation. This increase in plant output was assumed to occur uniformly over the first three years of operation.

The cost used in the base case analysis for fuel delivered to the plant was as determined for the labour-intensive program. The effect of adapting the use of a loader in the harvesting program to double production was also investigated. The delivered price of wood used to determine annual fuel cost for the plant includes the fixed unit cost per cord for harvesting and delivery and the overhead cost per delivered cord.

Table VI-2 summarize the results of analysis for the base case plant. Current dollar power prices are initially high because of the overhead cost associated with the first year of harvesting. The delivered price of wood on a per cord basis decreases as the quantity harvested increases. This trend continues up through 1987, after which the fuel cost in 1984 dollars is constant. Based on the gross power output of the plant, the equivalent uniform power cost in 1984 dollars is 57.9¢/kWh.

The sensitivity of power price to changes in several cost items was investigated to clarify the effect of estimating error and to identify the steps that may be taken to produce power more economically.

The sensitivity of power price to the changes investigated are summarized in Table VI-3. These results make evident the greater sensitivity of power cost to operating cost than to capital cost. A decrease in the inflation rate to zero over the life of the plant causes an increase in power cost because the benefit of repaying current debt with inflated dollars is lost.

YEAR	ANNUAL INFLATION RATE	POWER PROD'N (KWH/Y)	OPERATING COSTS WOOD ($/Y)	LABOUR ($/Y)	OTHER ($/Y)	AMORTIZATION OF CAPITAL ($/Y)	TOTAL COSTS ($/Y)	POWER COST ($/KWH)
1985	1.04	386000	96928	133536	62816	89864	383144	0.993
6	1.04	471667	85014	138877	65329	89864	379084	0.804
7	1.04	557334	102700	144433	67942	89864	404939	0.727
8	1.04	643000	121548	150210	70659	89864	432282	0.672
9	1.04	643000	126410	156218	73486	89864	445978	0.694
1990	1.04	643000	131467	162467	76425	89864	460223	0.716
1	1.04	643000	136725	168966	79482	89864	475037	0.739
2	1.04	643000	142194	175724	82662	89864	490444	0.763
3	1.04	643000	147882	182753	85968	89864	506467	0.788
4	1.04	643000	153797	190063	89407	89864	523132	0.814
1995	1.04	643000	159949	197666	92983	89864	540462	0.841
6	1.04	643000	166347	205573	96702	89864	558486	0.869
7	1.04	643000	173001	213795	100570	89864	577231	0.898
8	1.04	643000	179921	222347	104593	89864	596726	0.928
9	1.04	643000	187118	231241	108777	89864	617000	0.960
2000	1.04	643000	194603	240491	113128	89864	638086	0.992
1	1.04	643000	202387	250110	117653	89864	660015	1.026
2	1.04	643000	210482	260115	122359	89864	682821	1.062
3	1.04	643000	218902	270519	127254	89864	706539	1.099
4	1.04	643000	227658	281340	132344	89864	731206	1.137
2005	1.04	643000	236764	292594	137638	89864	756860	1.177
6	1.04	643000	246235	304298	143143	89864	783539	1.219
7	1.04	643000	256084	316469	148869	89864	811286	1.262
8	1.04	643000	266327	329128	154824	89864	840143	1.307
2009	1.04	643000	276980	342293	161017	89864	870154	1.353

PRESENT VALUE OF TOTAL COSTS (@ 10 %) = $4597480.12
PRESENT VALUE OF POWER PRODUCTION (@ 10 %) = 7934536 KWH
EQUIVALENT UNIFORM POWER COST (1984) = 0.579 $/KWH

TABLE VI-2. ANNUAL COSTS, POWER PRODUCTION AND POWER COST FOR A 175 kW STEAM ENGINE BASED PLANT

TABLE VI-3

SUMMARY OF CALCULATED POWER PRICES FOR THE

STEAM ENGINE BASED PLANT

COST CASE	POWER COST (1984 $/kWh)	CHANGE FROM THE BASE CASE
1. Base Case	0.579	-
2. Zero percent inflation	0.636	+ 9.8%
3. Labour cost reduced by 15%	0.548	- 5.4%
4. Wood cost reduced by 15%	0.555	- 4.1%
5. Capital cost reduced by 10%	0.569	- 1.7%
6. Capital cost increased by 10%	0.590	+ 1.9%
7. Use of a loader in harvesting operation	0.558	- 3.6%
8. Use of loader in 2nd year of harvesting operation Labour cost reduced by 15% Capital cost reduced by 10%	0.516	-10.9%

Reduction of total labour cost by 15%, as would be possible by decreasing the wage of the boiler operators from $12/h to $10/h, decreases the power cost to 54.8¢/kWh. A 15% decrease in fuel cost, such as by a corresponding increase in the productivity of the harvesting workers, leads to a lower power cost of 55.5¢/kWh. Reduction of the capital cost of the plant by 10%, this being possible for I & NA because of exemption from taxes, reduces the power cost to 56.9¢/kWh. Doubling harvesting productivity by using a loader in the operation, starting in the second year, reduces power cost to 55.8¢/kWh. This step could be taken if the workers could properly maintain the additional equipment. By combining a number of cost cutting measures - using a loader in harvesting, reducing labour cost 15% and reducing capital cost 10% - it would be possible to produce power at a cost of 51.6¢/kWh.

The cost of power based on the net power output of the plant is considerably higher than the values shown, which are based on gross power output. Using the estimated power consumption of the community only, the power production cost on a net power basis is about 81.8¢/kWh. The extremely high cost of power via this calculation is due to the relative high proportion of the power output of such a small plant needed to drive the materials handling and boiler equipment, as well as the low utilization factor (annual production/annual production possible under continuous operation) of the plant, which is about 42%. A utilization factor of this magnitude is not unusual for small stand-alone systems capable of handling cyclic peak loads.

B. Steam Turbine Based Plant

The steam turbine based plant has an output capacity of 140 kW and a lower initial investment. Because of the lower plant capacity the annual output of the plant has been allowed to increase from 386,000 kWh in the first year of operation to the ultimate output of 549,900 kWh within two years rather than the four years allowed in the base case analysis. At a 10% interest rate, the uniform annual payment of principal and interest for the plant is $76,346.

The equivalent uniform power cost in 1984 dollars, allowing for inflation at 4% annually over the 25-year life of the plant, is 65.9¢/kWh. This is higher by 8¢/kWh than the power cost for the steam engine based plant. Reduction of the delivered wood cost by 15% over the life of the plant, decreases the power price to 62.9¢/kWh.

Considering the higher power price and the less than adequate output capacity of the power plant, use of a steam turbine is considerably less attractive than using a steam engine for power generation at the size appropriate for Fort Ware.

C. Steam Engine Based Plant with Heat Recovery

An economic analysis was conducted for the steam engine based plant with recovery of waste heat for use in the school and community centre. Estimates used in this analysis for annual heat use have been given previously in Chapter III, Section B. The

design heat demand for the heat recovery circuit is 1.4 GJ/h. The annual heat load was estimated to be 1,247 GJ for space heating and 128 GJ for domestic hot water. This energy use, with allowance for conversion efficiency, translates into an annual diesel fuel consumption of 55,212 L/yr. At a cost of $0.80/L for diesel fuel the credit to the operating cost which would arise by displacement of this diesel fuel consumption is $49,170/y.

To allow for the time needed to construct the community centre and addition of a secondary heating circuit to supply thermal energy to the school, the use of waste heat by these facilities was assumed to increase from zero in the first year of operation to full load in the sixth year of operation in equal increments (11,040 L/y). The credit used for the analysis was determined assuming a cost of diesel fuel in 1984 of $0.80/L, with a subsequent fuel cost increase at 4% annually over the life of the plant.

The results of the economic analysis are given in Table VI-4. This tabulation is based on the calculated capital and operating costs, and wood fuel of the same cost as used for the base case plant. With heat recovery, the cost of produced power is 53.3¢/kWh.

The sensitivities of the power cost to various changes in capital and operating costs are summarized in Table IV-5. As with the base case, reduction of inflation to zero causes an increase in the cost of power. Reduction of labour cost by 15% by a wage reduction reduces the power cost by 6%. The greatest reduction in power cost is achieved by combining several cost cutting measures; use a loader in and after the second year of harvesting; reduce labour cost 15%; reduce capital cost (exemption from taxes) 10%

YEAR	ANNUAL INFLATION RATE	POWER PROD'N (KWH/Y)	OPERATING COSTS WOOD ($/Y)	OPERATING COSTS LABOUR ($/Y)	OPERATING COSTS OTHER ($/Y)	AMORTIZATION OF CAPITAL ($/Y)	HEATING CREDIT ($/Y)	TOTAL COSTS ($/Y)	POWER COST ($/KWH)
1985	1.04	386000	96928	133536	63648	99008	0	393120	1.018
6	1.04	471667	85014	138877	66194	99008	9551	379543	0.805
7	1.04	557334	102700	144433	68842	99008	19876	395106	0.709
8	1.04	643000	121548	150210	71595	99008	31001	411360	0.640
9	1.04	643000	126410	156218	74459	99008	42997	413099	0.642
1990	1.04	643000	131467	162467	77438	99008	55889	414490	0.645
1	1.04	643000	136725	168966	80535	99008	58125	427109	0.664
2	1.04	643000	142194	175724	83756	99008	60450	440233	0.685
3	1.04	643000	147882	182753	87107	99008	62868	453882	0.706
4	1.04	643000	153797	190063	90591	99008	65382	468077	0.728
1995	1.04	643000	159949	197666	94215	99008	67998	482840	0.751
6	1.04	643000	166347	205573	97983	99008	70718	498193	0.775
7	1.04	643000	173001	213795	101902	99008	73546	514161	0.800
8	1.04	643000	179921	222347	105979	99008	76488	530767	0.825
9	1.04	643000	187118	231241	110218	99008	79548	548037	0.852
2000	1.04	643000	194603	240491	114626	99008	82730	565998	0.880
1	1.04	643000	202387	250110	119212	99008	86039	584678	0.909
2	1.04	643000	210482	260115	123980	99008	89480	604105	0.940
3	1.04	643000	218902	270519	128939	99008	93060	624309	0.971
4	1.04	643000	227658	281340	134097	99008	96782	645321	1.004
2005	1.04	643000	236764	292594	139461	99008	100653	667173	1.038
6	1.04	643000	246235	304298	145039	99008	104679	689900	1.073
7	1.04	643000	256084	316469	150841	99008	108866	713536	1.110
8	1.04	643000	266327	329128	156874	99008	113221	738117	1.148
2009	1.04	643000	276980	342293	163149	99008	117750	763681	1.188

PRESENT VALUE OF TOTAL COSTS (@ 10 %) = $4230233.63
PRESENT VALUE OF POWER PRODUCTION (@ 10 %) = 7934536 KWH
EQUIVALENT UNIFORM POWER COST (1984) = 0.533 $/KWH

TABLE VI-4. ANNUAL COSTS, POWER PRODUCTION AND POWER COST FOR A 175 kW STEAM ENGINE BASED PLANT WITH HEAT RECOVERY

TABLE VI-5

SUMMARY OF CALCULATED POWER PRICES FOR A

STEAM ENGINE BASED PLANT WITH HEAT RECOVERY

COST CASE	POWER COST (1984 DOLLARS/ kWh)	CHANGE (%)
1. Base Case	0.533	-
2. Zero Percent Inflation	0.598	+12.2
3. Labour cost reduced by 15%	0.501	- 6.0
4. Wood cost reduced by 15%	0.508	- 4.7
5. Wood and labour cost reduced by 15%	0.477	-10.5
6. Use of a loader in 2nd year of harvesting operations Labour cost reduced by 15% Capital cost reduced by 10% Heat load increases uniformly to 2,750 GJ in 1995	0.430	-19.3

and continue increasing recovery of waste heat to a level of double the amount used for the base case analysis. These steps reduce the power cost to 43¢/kWh, a value nearly equal to the cost of power on a gross output basis to a diesel-fired plant. On a net power basis, the power cost increases to 60.8 ¢/kWh.

D. Diesel-Fired Power Plant

For comparison purposes, the cost of power was determined for a diesel-fired power plant yielding a net power output similar to that for the steam engine based power plant. The plant was sized for an output of 150 kW under continuous operation, an output comparable to the output possible from a steam engine based plant. Costs were determined for construction of a complete plant, including building and plant operation. The scope of the cost estimates was identical in concept to that for the wood-fired plants. It was assumed that the plant would utilize three diesl electrical generators each having a continuous rating of 50 kW.

The capital cost estimate for the diesel-fired plant was derived partly from cost data obtained from I & NA which applied to the existing 132 kW power system. The balance of the costing was done by adapting data obtained for use in the analysis of wood-fired plants. The capital cost of the complete plant may be summarized as follows:

	1984 $
Diesel electric generators with control system	147,700
Fuel Storage	93,000
Building	38,700
Electrical Distribution	22,700
Site Preparation	2,000
SUBTOTAL	304,100

INDIRECT COSTS		
Engineering		$ 21,300
Contractors overhead and fee		45,600
		66,900
	SUBTOTAL	371,000
Cost of delivery of equipment and supplies		6,200
	GRAND TOTAL	$377,200

Based on an average service life of 25,000 h and an accumulation of 3000 h/y on each engine, the diesel engines would have to be replaced or completely rebuilt approximately every eight years. Consequently, the cost of replacing this equipment at the start of years nine and seventeen of the life of the plant was included in the life-cycle cost estimate. This allowance makes the economic analyses of the wood-fired and diesel-fired plants more directly comparable.

Operating costs include operating labour, maintenance, fuel, administration and insurance. Labour cost was determined for a rate of $12/h, the same as that used for the wood-fired plants. Fuel cost was determined using a specific fuel consumption figure of 0.34 L/kWh (electric), a value typical for a turbo-charged diesel engine/generator operating at 50% load. Fuel consumption varies in proportion to the annual plant production, which increases in equal increments from 273,000 kWh in the first year to 455,000 kWh in the fourth year. This schedule for power consumption of the community is the same as used for the community in the analysis for the steam engine based power plant.

Operating costs for the plant may be summarized as follows:

	1984 DOLLARS
Labour 1040h @ $12/h	12,480
Maintenance	6,800
Administration and general overhead	6,200
Insurance	3,700
Diesel fuel	
1985	74,260
1986	90,760
1987	107,260
1988-2009	123,760

Table VI-6 presents a tabulation of the annual costs, in current dollars, for operation of the plant at the estimated power output levels, as well as the cost of power in current dollars and equivalent 1984 dollars. The estimated uniform power cost in 1984 dollars was determined by equating the present value of total costs to the present value of revenue. Power is clearly produced at a much lower cost by the diesel-fired plant (42.6¢/kWh) than comparably sized steam engine based plant (57.9¢/kWh) with wood harvested using the labour intensive program.

The sensitivity of power cost to various influential cost factors was also investigated. The results are shown in Table VI-7.

The results indicate the greater sensitivity of power cost to operating costs than the cost of debt amortization. Reduction of the inflation rate to zero from 4% leads to an increase in power cost in 1984 dollars because the benefit of repaying money borrowed in 1984 with future inflated dollars is lost.

YEAR	ANNUAL INFLATION RATE	POWER PROD'N (KWH/Y)	OPERATING COSTS DIESEL ($/Y)	OPERATING COSTS LABOUR ($/Y)	OPERATING COSTS OTHER ($/Y)	AMORTIZATION OF CAPITAL ($/Y)	TOTAL COSTS ($/Y)	POWER COST ($/KWH)
1985	1.04	273000	77230	13000	17368	49206	156804	0.574
6	1.04	333670	98166	13520	18063	49206	178955	0.536
7	1.04	394330	120653	14061	18785	49206	202705	0.514
8	1.04	455000	144782	14623	19537	49206	228148	0.501
9	1.04	455000	150573	15208	20318	49206	235305	0.517
1990	1.04	455000	156596	15816	21131	49206	242749	0.534
1	1.04	455000	162860	16449	21976	49206	250491	0.551
2	1.04	455000	169374	17107	22855	49206	258542	0.568
3	1.04	455000	176149	17791	23769	56046	273755	0.602
4	1.04	455000	183195	18503	24720	56046	282464	0.621
1995	1.04	455000	190523	19243	25709	56046	291520	0.641
6	1.04	455000	198144	20013	26737	56046	300939	0.661
7	1.04	455000	206069	20813	27807	56046	310735	0.683
8	1.04	455000	214312	21646	28919	56046	320923	0.705
9	1.04	455000	222885	22512	30076	56046	331518	0.729
2000	1.04	455000	231800	23412	31279	56046	342537	0.753
1	1.04	455000	241072	24349	32530	62846	360796	0.793
2	1.04	455000	250715	25323	33831	62846	372714	0.819
3	1.04	455000	260744	26336	35184	62846	385109	0.846
4	1.04	455000	271173	27389	36592	62846	398000	0.875
2005	1.04	455000	282020	28485	38055	62846	411406	0.904
6	1.04	455000	293301	29624	39578	62846	425348	0.935
7	1.04	455000	305033	30809	41161	62846	439848	0.967
8	1.04	455000	317235	32041	42807	62846	454929	1.000
2009	1.04	455000	329924	33323	44519	62846	470612	1.034

PRESENT VALUE OF TOTAL COSTS (@ 10 %) =	$2389482.24
PRESENT VALUE OF POWER PRODUCTION (@ 10 %) =	5614382 KWH
EQUIVALENT UNIFORM POWER COST (1984) =	0.426 $/KWH

TABLE VI-6. ANNUAL COSTS, POWER PRODUCTION AND POWER COST FOR A 150 kW DIESEL-FIRED POWER PLANT

TABLE VI-7

SUMMARY OF CALCULATED POWER PRICES

FOR THE DIESEL-FIRED PLANT

COST CASE	POWER COST (1984 DOLLARS/ kWh)	CHANGE (%)
1. Base Case	0.426	-
2. Zero percent inflation	0.458	+ 7.5
3. Diesel fuel consumption or cost increased by 15%	0.466	+ 9.4
4. Capital cost of plant increased by 15%	0.438	+ 2.8
5. Non-fuel or labour operating costs increased by 15%	0.431	+ 1.2

VII. MANPOWER AND TRAINING REQUIREMENTS

A. Manpower

Men are required for fuel harvesting and for plant operation. The manpower requirement of the fuel harvesting operation has been discussed previously in Chapter V and will only be summarized here for ease of later reference. The manpower required for plant operation has been discussed in Chapter IV where related to the sizing and design of the plant and determining the plant operating cost. These manpower requirements will also only be summarized here.

A manpower use plan has been developed taking into account the current lack of skilled tradespersons and professionals in Fort Ware, but recognizing that over the life of the project a primary objective is to employ Band members in all positions involved in the operation of the facility. Initially, manpower from outside the community must be used, but through on-the-job training, augmented by seminars and courses given in the community, Band members will gradually assume the roles of these personnel.

1. Fuel Harvesting

The manpower requirements of the forest harvesting operation shift as implementation of the project progresses through various phases. Initially a Forester/Forest Technician from outside the community is required to direct the forest inventory and conduct work needed to obtain a Timber Sale Licence from the Province. Two Band members will

be recruited and assist the Forester. Upon receipt of tenure for the resource a superintendent from outside the community is required to direct woods operations. A superintendent trainee from the Band will work under the superintendent as a working foreman and assist in day to day operations. This superintendent elect will preferably be chosen from the two assistants to the Forester.

As work progresses to fuel harvesting and delivery to the plant site under the recommended program, the woods crew will be increased to seven to eight cutters and two to four porters, these being Band members. The superintendent will oversee operations and report to I & NA and the consultant forester to ensure work is progressing effectively and meeting the requirements set forth by the Ministry of Forests.

Over the first year of fuel harvesting, refinements to the management structure and changes in responsibility will undoubtedly occur. In order for the project to be viable over the long-term a Band member must be fully trained to function effectively as a superintendent elect/working foreman. He must direct day to day operations and ensure that harvesting quotas are met, as well as report to the plant owner/operator to ensure that problems are solved as they arise, supplies are maintained and work is progressing according to a master plan.

Annual reviews of forest operations will be needed by an outside Forester/Forest technician to ensure continued adherence to the requirements of the Ministry of Forests and give guidance on how to improve efficiency and keep pace with

improvements in forest management practices. After about two years or, possibly, only one year of operation using the labour intensive harvesting program, sufficient experience will have been gained to introduce a loader to increase productivity and reduce fuel cost.

In summary, nine to twelve Band members will be employed up to 100 days per year once operation of the facility has stabilized. This employment will be available for a scheduled period of time each year and could be arranged to best suit the availability of manpower in the community. With each year of operation, regular workers in the fuel harvesting operation would become increasingly experienced and confident and new workers could be integrated into the existing work force with increasing ease. Based on the past history of projects in the community, it would be advantageous to train a much larger workforce than would be required at any one time. The work crew could then drawn from this pool of workers allowing operations to continue effectively in spite of absenteeism or temporarily conflicting interests of some Band members.

2. Plant Operation

As done for the fuel harvesting operation, the sources of plant personnel has been chosen to allow sufficient time for education and training of Band members for plant operation and maintenance. The minimum training requirements for operators of the boiler are established by the Provincial government and dictate to a large degree the approach taken for manning the plant.

Operation of the plant requires one Fourth Class power engineer, three certified boiler operators and one man for the fuel yard. Initially, the four boiler operators must be obtained from outside the community. The yard worker would be a Band member. The Fourth Class engineer is the chief plant engineer and responsible for all facits of plant operation and supervision of the three shift engineers. In addition, he should have authority over the fuel harvesting operation to ensure regular supply of fuel is maintained. In this role he functions as an overall manager of all day to day project operations. Because of the responsibility level of the plant manager, someone used to working unsupervised or with minimal supervision would be essential.

The responsibility for operation of the plant could be transferred to Band members in the first year of operation by coordinating correspondence courses and on the job training. Prior to commencing plant operation, six candidates for boiler operators should be chosen from the community. These candidates should be enrolled in a correspondence course for boiler operators, which would normally take four months to complete. Upon completion or during the course these boiler operator candidates will be employed as trainees at the plant, functioning under the immediate supervision of the shift chief plant engineers. During the first year of operation some or, hopefully, all trainees will be eligible to write the Provincial examination for certification. Upon successful completion of the Provincial examination, the trainees may replace the shift boiler operators obtained from outside the community.

Allowing for people dropping out of the training program, and perhaps slow progress towards achieving certification as boiler operators, three shift engineers could

likely be trained from the community after a six month period. Shift engineers from outside the community would then no longer be needed. Perhaps two or more Band members interested in a Fourth Class engineering certificate should be chosen from the group of certified boiler operators. Training of these personnel towards obtaining a Fourth Class certification should be given by correspondence courses and in-plant work, under the guidance of the plant engineer, leading to certification by the end of the first year or so of operation. At this point the plant could be fully manned by Band members.

One person is required for fuel preparation and to assist plant operators in routine maintenance. This person requires general skills for operation and maintenance of the tractor and fuel preparation equipment. To avoid interruptions in the fuel preparation section of the plant, two or more Band members should be capable of functioning in this position.

B. Training Requirements

The subject of manpower training arises when considering the skills required to effectively undertake the work in the fuel harvesting operation and the boiler plant operation. Every reasonable effort has been made to minimize the level of skill required to operate the complete facility safely and efficiently with the intent that this approach would result in training requirements which are achievable in Fort Ware.

1. Fuel Harvesting

Training of cutters and porters in the wood harvesting operation has been discussed in Chapter V, with the conclusion being that adequate training could be given on the job. For those interested in upgrading their training in the area of forest management to become a forest technician, courses are available at colleges located at major centres in the Province. Unfortunately, such courses are not presently offered outside of the college environment and may be unattractive to most in Fort Ware. A more suitable, and probably better received, means of expanding knowledge of forest management in Fort Ware would be field seminars, much like the seminar on this topic held in mid-1984. Such instruction would be a beneficial addition to training given on the job in areas of equipment use and maintenance, tree falling and safety practices.

2. Plant Operation

As in other provinces of Canada, only a person holding a power engineer's or boiler operator's certificae may operate a power boiler in British Columbia. The boiler was sized to have a heating surface of less than 100 m^2, enabling a Fourth Class power engineer to function as chief plant engineer and certified boiler opeartors to function as shift engineers, in compliance with the Boiler and Pressure Vessel Safety Act and Regulations.

The Act and Regulations state various equivalent levels of experience required by applicants for a Fourth Class power engineer's certificate. Of these requirements, the most

relevant under Section 16 of the Act states that an applicant must have been employed for a period of not less than 12 months as a power engineer trainee in a power plant that has a heating surface exceeding 10 m^2. When an applicant has successfully completed a Fourth Class power engineering course at an accredited vocational school or through a correspondence school, the period of employment under Section 16 of the Act is reduced to six months.

The qualifications required by an applicant for a boiler operator's certificate are either eight months employment as a power engineer trainee in a high or low pressure steam plant with a heating surface exceeding 3 m^2 or four months employment following successful completion of a boiler operator's course at an accredited vocational or correspondence school.

Correspondence courses towards certification as a Fourth Class power engineer and a boiler operator are offered by the Vancouver Vocational Institute (VVI) in Vancouver. These courses prepare applicants to write Provincial examinations and enter employment to gain the experience needed for certification.

The normal time stated by the VVI to complete the correspondence studies are four months for the Boiler Operator course and six months for the Fourth Class Engineer course. Students are allowed up to one year to complete these courses. Prerequisites are not required for either course. In general, students should have the following characteristics and abilities:

- good command of oral and written English;
- physical strength and stamina sufficient to withstand demands associated with this trade;
- normal hearing, eyesight and colour vision;
- manual dexterity and normal hand-eye coordination;
- good mathematical and mechanical aptitude, both practical and theoretical.

Full descriptions of the Boiler Operator and Fourth Class Power Engineer courses are available in the Program Content Guide for Power Engineers produced by the Councelling Department of the VVI. Subjects covered in the Boiler Operator course include:

- low pressure boiler construction;
- low pressure boiler operation;
- pumps and piping;
- heating systems;
- electricity and plumbing;
- safety and high pressure boilers.

Expanded instruction is given in the Fourth Class Power Engineers course, covering the following subjects:

- mathematics, mechanics;
- thermodynamics, drawing;
- boiler construction, piping;
- combustion;

- electricity, instrumentation;
- maintenance, safety;
- feedwater pumps;
- heating boilers;
- turbines, engines;
- refrigeration, air compression;
- plants, lubrication;
- boilers.

The material covered in these courses follows the syllabus prepared by the Inter-Provincial Standardization Examining Authority.

The correspondence course program is structured to allow students to learn the material contained in the applicable textbook, prepare written answers to questions and submit these answers by mail for marking. Instructors make comments and suggestions and return the assignments. An examination administered by VVI is written upon completion of the course material.

VIII. TENTATIVE PLAN AND SCHEDULE OF ACTIVITIES FOR IMPLEMENTING THE PROJECT

A. Major Considerations

Because of the variety of problems associated with undertaking a fuel harvesting operation, plant construction and plant operation in Fort Ware, a cautious and conservative implementation plan has been developed. The plan includes several key milestones where a decision may be made to abandon the project or continue to the next phase. The investment committed to the project increases with each phase of the project, this increase being substantial when plant construction is undertaken, and for this reason, the plan includes a preliminary phase. This preliminary phase is intended to act as a pilot project supplying information sufficient to reassess the project with some confidence and with recognition of site specific factors.

The plan for the project makes the tacit assumption that the owner of the plant would be I & NA. Operation and management of the plant was assumed to be the responsibility of I & NA initially, with transfer to the Band occurring in the future based on an appraisal of this option at the time.

The plan for the project should be considered as a guide only since changes should be made as work progresses through the phases of the project to benefit from the latest available information.

The plan for the project was developed with consideration of the impact of restrictions imposed by the local climate on outdoor work and shipment of equipment and supplies into Fort Ware. In addition, a steady pace of work was desired to maintain enthusiasm

in the project, assist in maintaining continuity of personnel involved and avoid unnecessary delay in making electricity available to the community.

B. The Plan and Schedule

1. Phase 1

The first phase of the project is a pilot test of the fuel harvesting operation. This activity is intended to answer several questions that have been raised during this study relating to use of local manpower:

- is there sufficient interest in the project and the opportunity for employment to undertake the project?

- could the Band members be trained to fill the positions required?

- would continuous employment involving regular workhours be of sufficient interest to Band membres to maintain the required workforce?

- is there undue risks of injury to Band members through improper use of equipment or poor safety practices.

The pilot test would involve the following activities:

- obtain a Special Use Permit from the Ministry of Forests for construction of the main haul road;

- beginning in April/85 involve a consultant Forester/ Forest technican to supervise survey of a main haul road and conduct a forest inventory;

- hire a work crew from the community to assist in survey work under the direction of the Forester/ Forest Technician;

- hire a superintendent from outside the community to direct clearing the right-of-way for the main haul road, construction of the road, and cutting and delivery of wood to the plant site;

- expand the Band work crew to accomplish the various tasks needed to build the road and harvest fuel. Train one Band member as a working foreman to assist the Superintendent;

- involve personnel from I & NA and the Forester/Forest Technician to monitor the work, assess the ability of the work crew to conduct the work, and assess the social impact of the project;

- based on the productivity of the cutters and porters and the cost of road construction, labour and equipment, re-evaluate the delivered cost of fuel. Re-evaluate the economics of the power plant.

Phase 1 could begin in April of 1985 or earlier, depending on weather conditions, and would continue through to the end of June. By the completion of Phase 1, if not before, the viability of undertaking the fuel harvesting operation for

the power plant will be evident. Successful completion of Phase 1 would be justification for proceeding to Phase 2, which would involve further fuel harvesting, as well as plant design and construction. Failure to achieve a satisfactory fuel harvesting program would possibly be justification to terminate or modify the project as deemed appropriate.

If the project was terminated at the end of Phase 1, the effort would not be wasted. The developed road would be beneficial to the community for harvesting fuel wood in future, while the wood delivered to the plant could be sold for local heating use. Minimal new equipment is involved and could be sold to Band members or used in educational programs by I & NA.

2. Phase 2

Phase 2 involves design of the plant, ordering and installation of equipment, construction of plant facilities and completing delivery of a year's supply of wood to the plant. With attention to scheduling of design and construction work and attention to deadlines for equipment shipment to Fort Ware it is probable that plant construction could be completed before the end of 1985. This phase would involve major expenditures. At the start of Phase 2, input from the Band should be requested to find the best fit of the project to the community. Periodic meetings on progress may be valuable as a means of maintaining interest in the project and giving the Band an opportunity for comment.

Approximately six months before completion of the plant, candidate boiler operators should be recruited and enrolled

in a boiler operators correspondence course. The correspondence course should be given under the direction of the teachers at the school and possibly augmented by other educational programs to ensure the candidates have the support and guidance needed to complete the course work successfully.

Certified boiler operators from outside the community should be hired towards the end of this Phase in preparation for plant startup.

3. Phase 3

Phase 3 involves startup and operation of the plant, as well as training of Band members to operate and manage the facility on a day to day basis. As native apprentice boiler operators become certified by the Provincial government, they will assume the responsibilities of the operators brought in from outside the community. An objective during the first year of operation would be to fill all positions at the plant and in the fuel harvesting operation from the community.

Throughout the first year or two of Phase 3 monitoring and direction of work in Fort Ware by I & NA staff would be needed. Gradually, as Band members became more experienced, the Band could assume increasing responsibility for plant and fuel harvesting operations.

The demand load on the plant would have to be monitored regularly to avoid excessive demand loads and plan for future

expansion, if necessary. The cost of producing power at the plant should be impressed on members of the community to assist in moderating power demand and consumption. The limits of the plant and the affect of their power use habits should be made clear to the Band.

IX. BENEFITS TO THE COMMUNITY OF A WOOD-FIRED POWER PLANT

Many immediate and long-term benefits would result from installation of a wood-fired power plant in the community, though some are dependent on the extent to which the Band would accept and participate in such a project. Many of these potential benefits can only be assessed with confidence once all or part of the project is implemented.

The immediate benefits of such a project are the creation of regular employment in the community and the training of these employees in logging skills and boiler plant operation. The project would create, under the labour intensive program recommended for initial implementation, employment for nine to twelve people in the fuel harvesting operation for about half a year on a regular basis. A further four boiler operator positions and one yard worker position would be created at the plant on a year-round basis. The total earnings amount to $95,000 for the fuel harvesting crew when the plant is operating at its expected annual production, and $128,400 for the plant work force. These amounts are based on a wage rate towards the upper end of what might be appropriate given the circumstances at Fort Ware. A 15% reduction in the wages paid and, therefore, the total earnings, may still yield a wage rate sufficient to motivate the workers. The training received by workers in the fuel harvesting and plant operations would increase their understanding of this technology in general, improve their ability to operate equipment safely and properly, and improve their ability to find work outside the community, if this is desired.

Other benefits of the project include:

- improvement in the stability of employment available in the community, with consequent improvement in the stability of the living conditions of the workers;

- greater autonomy of the community and insulation from future increases in diesel fuel prices;

- improved growth conditions for softwoods in the areas from which the hardwoods have been removed for fuel use;

- development of managerial and supervisory skills that will enable the Band to better manage the operation and growth of the community.

X. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. The peak electrical demand of the community as a whole is expected to be 176 kW once electricity has been distributed to all residents and full use is being made of the available electrical power. The initial electrical demand of the residents will be primarily for lighting and small appliances but use will grow quickly, possibly reaching the estimated demand values within four to five years.

   The annual consumption of the community is expected to grow to 455,000 kWh.

2. The thermal demand in the community most suitable for supply using waste heat from the power plant is that of the school and the community centre. These facilities are expected to have a combined peak demand of 1.4 GJ/h and an annual consumption of 1,375 GJ. Other buildings could be supplied using waste heat, but they would have to be near the plant site.

3. A wood-fired power plant having a continuous rated output of 175 kW is best suited to Fort Ware for reasons of scale of the fuel harvesting operation and lesser requirements for training boiler operators. To achieve this power output while keeping the size of the boiler and the wood requirements of the plant within practical limits, a steam engine must be used as the prime mover for the generator. The boiler for this size of plant has a heating surface area of

less than 100 m^2 and, therefore, could be operated under the control of a chief engineer having a Fourth Class certificate, and three shift engineers having boiler operators certificates.

The net power output of a steam engine based plant is 140-145 kW because of the power required to operate the boiler and the materials handling equipment. This power output is substantially below the projected peak demand of the community of 176 kW. Enlarging the size of the plant to satisfy the peak demand of the community is not attractive because of the need in this case for one Third Class and three Fourth Class engineers to operate the plant, as well as the need for an increased scale of fuel harvesting.

4. Use of a steam turbine instead of a steam engine, with the balance of the plant unchanged, limits the gross output of the plant to 140 kW and a net output of 105 kW, substantially less than the 175 kW gross output which could otherwise be achieved. Consequently, a steam engine is the preferred prime mover for the plant.

5. The most suitable location for a wood-fired power plant is north of the school complex on unoccupied land near the start of the Kwadacha trail. This site is on the eastern edge of the area identified by I & NA for future community growth and would, therefore, have a minimal impact on residents. Delivery of wood would occur along the Kwadacha trail, which is away from dwellings and the school, reducing safety hazards, and dust and noise nuisances. The siting of the plant is sufficiently close to the school and proposed community to justify piping of hot water from the plant to these buildings to recover thermal energy.

The plant would occupy 0.77 ha of land in total. This land area is presently unoccupied but has been considered by I & NA for three housing sites.

6. The most suitable fuel handling system for the power plant involves delivery of logs cut and split in the woods to a length of 1.2 m and a maximum diameter of 20 cm, stacking of this cordwood in a storage yard to allow it to dry to 20% moisture content, then chipping of the cordwood on a semi-continuous basis for use. One yard worker is needed five days per week to recover logs from storage and feed them to the chipper. This person must also maintain and service the fuel handling and preparation equipment. A one year supply of fuel is kept at the plant at all times, essentially eliminating concern over delays which may occur in the harvesting operation.

7. The Crown forests within an eight-kilometer radius of Fort Ware are capable of supplying sufficient hardwoods for the plant for well in excess of twenty-five years of plant operation. The primary fuel for the plant would be Aspen, Cottonwood and Birch which are present in mature and immature mixed stands of softwoods and hardwoods. The most suitable means for the Band to obtain tenure to the resource from the Ministry of Forests is through a Timber Sale Licence.

8. The recommended fuel harvesting program involves:

   - harvesting from the Kwadacha West area initially, moving to the Kwadacha East and Finlay areas once hardwoods in the Kwadacha West area are exhausted. Including mature

stands only, there is at least a 5.7 year supply in the Kwadacha West area and an 11.5 year supply in the Kwadacha East and Finlay areas. Substantial additional resource is present in immature stands;

- utilizing skid trails to gain access to the forest and seven to eight cutters to fall trees, and cut and split them to the required size;

- transport of the cordwood using two to four porters, two tractors and two wagons from the woods to the storage area at the plant.

Once the harvesting crew has gained experience and proved itself capable of maintaining equipment properly and functioning reliably, a loader could be introduced to increase productivity and reduce the unit cost of delivered fuel. The decision to make this change in the harvesting operation can only be made with confidence after at least one year of operation under the recommended labour-intensive program.

9. Economic analyses were done for four plant designs using cost estimates made in this study. Three wood-fired plants were considered: a steam-engine plant; a steam turbine plant; and a steam engine plant with heat recovery. For comparison purposes a diesel-fired plant was investigated which had a net power output similar to the steam engine based plant.

For all cases, the uniform power cost in 1984 dollars which yielded equality between the present values of costs and revenues over the life of the plant was determined and used as the basis of comparison.

Some of the more important results are summarized below using gross plant output to determine power cost:

DESIGN	SCENARIO	POWER COST (1984 Dollars/kWh)
Steam Engine Based Plant	Base case	0.579
	- use a loader in and after the 2nd year - labour cost reduced 15% - capital cost reduced 10%	0.516
Steam Turbine Based Plant	Base Case	0.659
Steam Engine Based Plant with Heat Recovery	Base Case	0.533
	- use a loader in and after 2nd year - labour cost reduced 15% - capital cost reduced 10% - heat load increased to 2750 GJ by 1995	0.430
Diesel-Fired Plant	Base Case	0.426

The best wood-fired case above gives a power cost of $0.608/kWh, on the basis of power delivered to the community, considerably higher than the value shown, which is based on gross power output.

The least expensive means of supplying electricity to the community is by using a diesel-fired power plant. This conclusion is based solely on the capital and operating costs associated with power production and, thus, excludes social issues such as employment, education and training, and greater autonomy of the Band.

The benefit to the community of utilizing a wood-fired power plant would be substantial and should be considered when comparing the estimates of power cost for the wood-fired and diesel-fired plants. Use of a wood-fired power plant to generate electricity would create employment for nine to twelve people in the fuel harvesting operation, and five people in the boiler plant. These personnel would have training in established occupations and could find employment outside the community, if desired. Other potential benefits are creation of a local job market for youth finishing school, greater autonomy of the Band and insulation from increased oil prices, improved growth conditions in the logged areas, and the opportunity for the Band to gain managerial experience that will be of value in all of its other activities.

Of the three wood-fired plants examined, a steam engine based plant with heat recovery is the most economically attractive. If use of waste heat from the plant is encouraged in the

community to the degree that heat recovery double the estimated value is achieved by 1995, and other cost cutting measures are implemented, the power cost on a gross output basis could be reduced to $0.430/kWh.

10. The steam engine based plant (with and without heat recovery) is capable of delivering up to 140-145 kW to the community. This is less than the peak demand of 176 kW estimated for the community over the longer term. This shortfall will not be a problem for perhaps the first four to five years. Following this period, residential demand may have increased to a point where demands on the system will exceed capacity.

    In this case, the existing I & NA diesel-fired power plant could be used to synchronously generate peak power. Use of the existing diesel electric generators in this way has the benefits of allowing the wood-fired plant to operate as a base load system, which best suits its operating characteristics, and of making full use of the excellent response characteristics of the existing diesel power system. Controls would have to be added to bring the diesel electric generators on-line in phase with the power from the wood-fired plant.

11. Recruiting and training Band members to operate the power plant on a continuous basis is the part of the project most subject to failure. Recruiting and training Band members for the fuel harvesting operation is expected to be an achievable objective since harvesting activities are similar in many respects to what is now done to obtain fuel for domestic use and are familiar to some Band members who have worked for logging companies outside Fort Ware. The operators of the

power plant must pass correspondence courses, obtain work experience and pass the Provincial examinations before being certified. Information made available for this study indicates that little success with occupational training has been achieved to date, though some of these problems have been related to attempts to train Band members outside Fort Ware. With the support of the Band as a whole and involvement of the I & NA school teachers to assist Band members with this coursework, it is expected that a complete crew for the boiler plant could be trained. Normally the education and training period for a boiler operator totals eight months, while for a Fourth Class engineer it totals twelve months. Given the lack of formal schooling of Band members and their lack of familiarity with boilers, the training and education period will extend beyond these typical values.

Because of the need to attempt implementation of the project at a small scale to assess whether manpower is available and capable of functioning effectively, the first phase of the project has been limited to a forest inventory, and survey and clearing of a main haul road in the Kwadacha West area. Phase 1 will give information essential to evaluating the potential for success of the project, while keeping costs to a minimum.

Successful completion of Phase 1 would lead to Phase 2 of the project, which entails design and construction of the plant. Phase 3 covers commissioning and operation of the plant, a period of transition from I & NA management to, ultimately, Band management of the plant.

12. The boiler, furnace and steam engine/generator could only be shipped to Fort Ware via barge and riverboat. The lack of suitable riverboats and the presence of navigational hazards in the Finlay River are serious obstacles to construction of the plant. Alternate means of shipment of this heavy equipment are not available at present, and their development is expected to be more costly than use of riverboat shipments. The problems associated with equipment shipment should be considered early in the design phase (Phase 2) to minimize shipping costs, to ensure equipment can be delivered when needed and to make allowances in the design for whatever field assembly is necessary. Every effort needs to be made during the design to reduce field labour by pre-assembling and testing plant components.

B. Recommendations

1. Considering only the cost of producing power to serve the community, the most economical route is the use of a diesel-fired power plant. This would involve some local labour to supervise the engines and ensure they are properly maintained, but, at most, this would involve only one person, half time. The quantity of diesel fuel required annually for such a plant is substantial and consideration of the means of transport would be needed to identify the one that is most reliable and economical. A diesel plant would be a major source of noise in the community, so steps should be taken during the design of such a plant to attempt to minimize exhaust noise emissions.

2. Considering the need for employment and development of trade skills in Fort Ware, as well as the objective of minimizing

the cost of producing power, use of a wood-fired power plant with recovery of waste heat is recommended. The plant should be limited to the gross output possible when using a firetube boiler having a heating surface area of 100 m^2. A uniflow or high-speed counterflow steam engine should be used, since this will maximize electrical output from the plant. Based on the results from this study, the power plant will probably be limited to 175 kW in output. Heat should be delivered to the school and the community centre from a primary heating circuit using attached secondary heating circuits with their own pumps, valves and controls.

3. If a wood-fired plant is installed with a heating circuit, consideration should be given to supply of thermal energy to all future buildings constructed near the power plant. Each case will have to be analyzed individually to assess whether use of waste heat from the plant is justified.

4. Because of the potential for difficulties with recruiting and training personnel for the fuel harvesting and plant operation tasks, Phase 1 of the project should be implemented first, preferably beginning in April 1985 or sooner, weather permitting. Phase 1 involves a forest inventory, and survey and clearing of a main haul road to Kwadacha West, and could be completed in about three months. A Forestor/Forest Technician and a superintendent from outside the community would be involved in this Phase. Band members would assist the Forester and conduct the road surveying and clearing work. The trees felled should be cut and split to size, then delivered to the plant storage area for drying. Harvesting of this timber should proceed using the labour intensive program described in Chapter V.

5. An appraisal of progress and performance of the work program should be made in Phase 1 to obtain information needed to assess whether implementation of Phase 2 of the project is feasible. The main concern is whether or not a reliable and functional work crew can be organized from the Band members for a long-term project.

6. The project should be discussed with the Band to obtain their input in all areas, but, most importantly with regard to manpower availability, the desire for the employment involved, pay rates, and commitment to training the Band members to assume full operation of the plant. Success of the project is possible only if the Band gives its full support and motivates its members to obtain the required education and training to operate the boiler.

7. If the wood-fired plant is built and operated, inclusion of a loader in the harvesting program should be made as soon as practicable to reduce the cost of delivered fuel.

REFERENCES

Aquaterre Consultants Inc., 1982, "Water Well Evaluation, Geotechnical Study and Evaluation of Concrete Aggregate for Proposed School Addition and Teacherages, Fort Ware, B.C.", Report to Indian Affairs and Northern Development, November.

ASHRAE Handbook and Product Directory, 1980 Systems, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017

ASHRAE Handbook, 1979, Equipment, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017

ECO/LOG "Report on Pollution Control Objectives for the Forest Products Industry of British Columbia, Issued September, 1971 p. BC 205.0.

Edwards, W.C. and Cotton, T., 1982, "A Review of the Options Available to the Forest Industry for Producing Electricity from Wood Residues, Canadian Forestry Service, Ottawa, Report ENFOR C-185, March.

Environment Canada, 1984, personal communication

Fink, D.G. and Carroll, J.M., 1968, "Standard Handbook for Electrical Engineers", 10th Edition, McGraw-Hill Book Company, New York, N.Y.

Inland Waters Directorate, 1984, personal communication

Levelton, B.H. & Associates Ltd. 1981, "An Evaluation of Wood Waste Energy Conversion Systems - 1980", Canadian Forestry Service, Ottawa, Report ENFOR C-111, DSS Contract 42SS.KL229-0-4110, March.

Levelton, B.H. & Assoc. Ltd. 1980, "Wood Waste Fuels Preparation and Handling", Canadian Forestry Service, Ottawa, Report ENFOR C-95, DSS Contract 05SS.KL229-9-4378, December.

Lowe, B., B.C. Hydro and Power Authority, personal communication, October, 1984.

Nordell, E., 1961, "Water Treatment for Industrial and Other Uses", Reinhold Publishing Corp., New York

Perry, R.H., 1976, "Engineering Manual", 3rd Edition, McGray-Hill Book Company, New York, N.Y.

REFERENCES (Continued)

Lyle, O., 1947, "The Efficient Use of Steam", Her Majesty's Stationary Office, London, U.K., written for Fuel Efficiency Committee of Ministry of Fuel and Power.

Pratt, A.W., 1984, Personal communication regarding the design study for the electrical distribution network at Fort Ware.

Simons, H.A. (International) Ltd. and B.H. Levelton & Associates Ltd., 1983, "A Comparative Assessment of Forest Biomass Conversion to Energy Forms - Phase I", Energy Mines and Resources, Canada, Ottawa, Report ENFOR C-258, DSS Contract 43SS.KN107-1-4416, December.

SNC Ltd., 1981, "Production of Electricity by Wood-Fired Steam Engines for Remote Communities", Canadian Forest Service, Ottawa, Report ENFOR C-178, September.

Thurber Consultants Ltd., 1984, "Fort Ware Reserve Groundwater Supply", Report to Indian and Northern Affairs, Contract BC-83-84-96, Mag.

Urban Systems Ltd., 1984, Water System Design Drawings for Fort Ware, obtained from Indian and Northern Affairs, B.C. Region.

Woodruff, E.B. and Lammers, H.B., 1977, 1984, "Steam Plant Operation - Fourth and Fifth Editions", McGraw-Hill, Inc.

APPENDIX I

ABBREVIATED LIST OF EQUIPMENT SUPPLIERS

APPENDIX I

ABBREVIATED LIST OF EQUIPMENT SUPPLIERS

1. Fuel Preparation and Handling

Q.M. Industries — Conveyors, bins
Box 1868
Prince George, B.C. V2L 5K5
604-563-3604

United Agri Systems — Conveyors, bins
205 - 13395 76th Avenue
Surrey, B.C. V3W 6K2
604-591-5544

Peerless Page Industries — Bins
2829 Northland Avenue
Burnaby, B.C.
604-299-9501

Morbark Industries Inc. — Chipper
Box 1000
Winn, Michigan 48896
USA
517-866-2381

Nicholson Murdie Machines Ltd. — Chipper
327 Harbour Road
Victoria, B.C. V9A 3S2
604-385-6757

Hakmet Ltd. — Chipper
881 Harwood Blvd.
P.O. Box 248
Dorion, Quebec J7V 7J5
514-455-6101

2. Boiler

Bogot Brothers, Inc.
7065 West Belmont Avenue
Chicago, Illinois 60634
USA
312-637-3557
Represents Gebruder Weiss, K.G.
Waste Fuel Boiler Systems

Hurst Boiler Co., Inc.
P.O. Box 38
Highway 319
Coolridge, Georgia 31838
USA
912-346-3178

General Iron Works Co. Ltd.
2290 de la Metropole
Longueuil, Quebec J4G 1E6
514-670-1540

Volcano Inc.
c/o Salton Fabrication Ltd.
19011 96th Avenue
Surrey, B.C. V3T 4W2
604-888-0122

3. Steam Engine and Generator

Spillingwerk GmbH
2 Hamburg 11
Werftstrasse 5
West Germany
040-78-13-35
Telex 2-163-419 spil d

Skinner Engine Co.
337 West 12 Street
Erie, PA 16501
USA
814-454-7103

4. Steam Turbine and Generator

Terry Steam Turbine Co.
c/o Industrial Equipment Co. Ltd.,
7462 Progress Way
Tilbury Industrial Park
Delta, B.C. V4G 1E1
604-876-8881

Coppus Engineering Corp.
c/o General Equipment OLtd.
15 East Fourth Avenue
Vancouver 10, B.C.
604-876-8881

5. Condenser and Heat Exchanger

S.A. Armstrong Ltd.
c/o Kemp Agencies Ltd.
4603 Main Street
Vancouver, B.C. V5V 3R6
604-876-9297

6. Electrical Equipment

Federal Pioneer Ltd.
2551 Viking Way
Richmond, B.C. V6V 1N4
604-273-3711

Schmidtec Power Systems Ltd.
19214 94th Avenue
Surrey, B.C. V3T 4W2
604-888-0110

7. Water Treatment

Culligan Water Conditioning
No. 5 1355 - 77th Avenue
Surrey, B.C. V3W 6Y3
604-590-2291

Petwa Canada Ltd.
4120 23rd Street N.E.
P.O. Box 481
Calgary, Alta T2P 2J1
403-276-9963

APPENDIX II

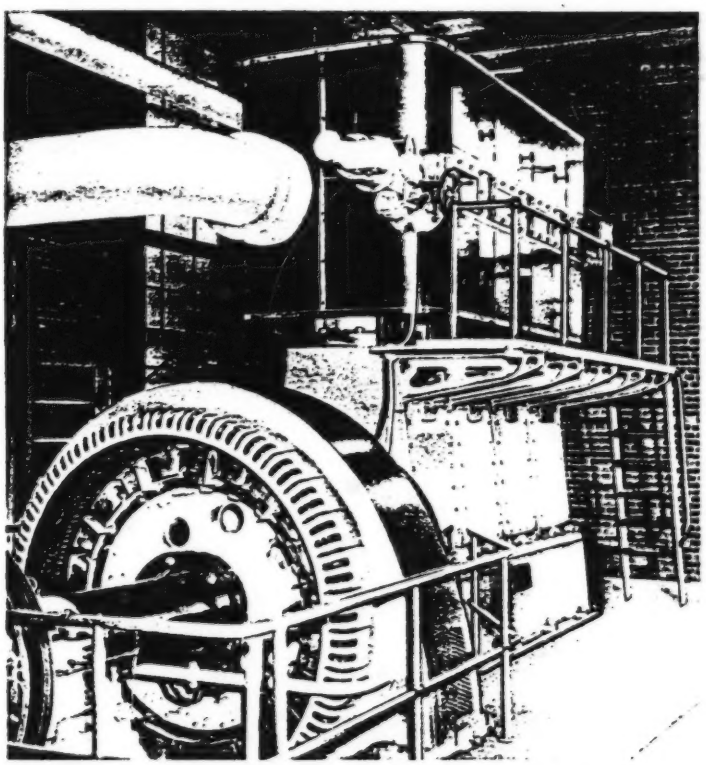
PERFORMANCE DATA FOR STEAM ENGINES MANUFACTURED BY SKINNER ENGINE CO. AND SPILLINGWERK GmbH

Bulletin: STE-1280

SKINNER

UNIVERSAL UNAFLOW STEAM ENGINES

MULTI-CYLINDER • VERTICAL TYPE



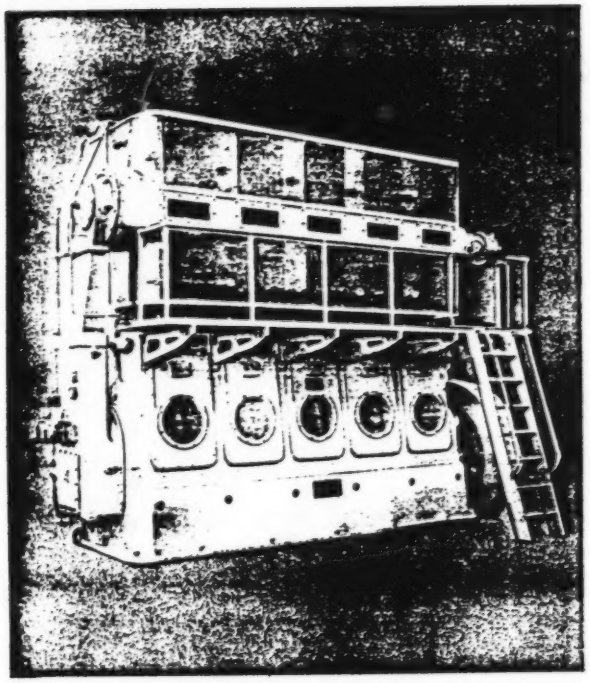
FOR INDUSTRIAL AND MARINE APPLICATION

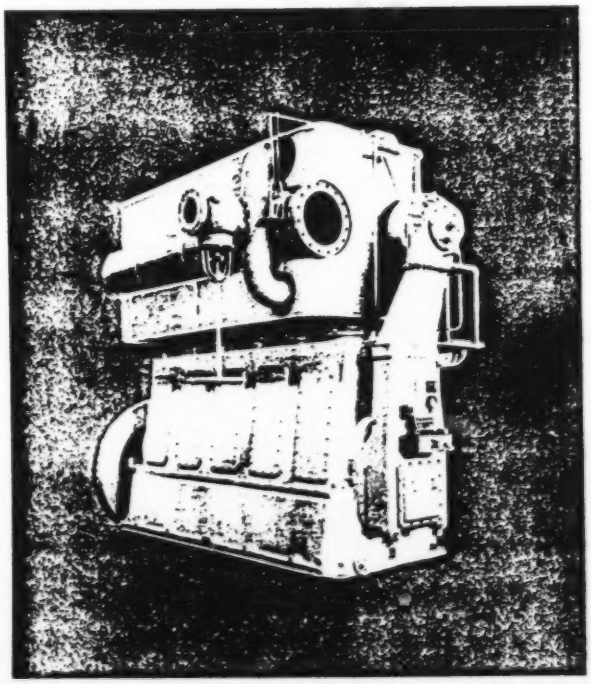
AVAILABLE SIZES:
300
TO
15,000
HORSEPOWER

- MAINTAINED ECONOMY
- HIGH DEPENDABILITY
- LOW MAINTENANCE COST
- MAXIMUM ACCESSIBILITY

Progress Through Performance . . . That's SKINNER

SKINNER A WORD ABOUT STEAM ENGINES . . .





With todays energy needs, SKINNER "UNIVERSAL UNAFLOW" Steam Engines of the Multi-Cylinder Vertical Type can provide unfailing, dependable power . . . to generate electricity . . . to drive compressors and pumps . . . in refrigeration and air conditioning . . . for hundreds of manufacturers (including: saw mills, sugar refineries, furniture plants, incinerator sites and petrochemical processing), office buildings, hospitals, schools and institutions.

Ideally suited where limited space conditions exist. For noncondensing or condensing operation, with automatic change for either condition. Built for constant or variable back pressure; medium or moderately high initial pressures, saturated or superheated steam.

Low pressure exhaust steam - a by-product of the steam engine - is usable for space heating, water heating, absorption type air conditioning, and a variety of manufacturing processes.

FRONT COVER PHOTO

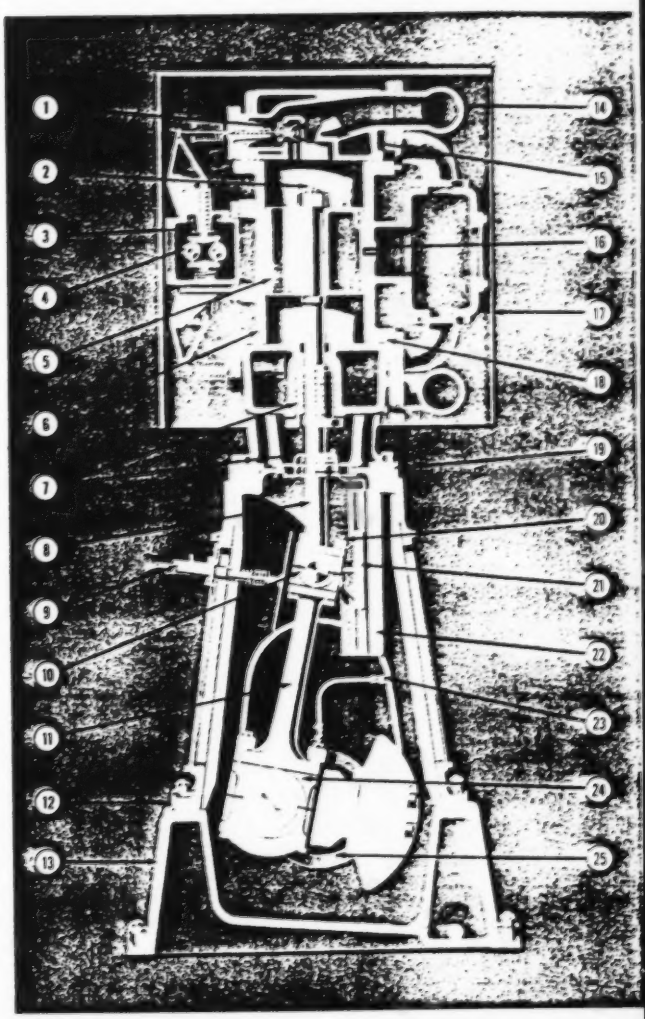
In continuous operation since 1950, one of six 1250 - kw — (4) cylinder "Universal Unaflow" Engines, in furniture plants of one manufacturer.

Progress Through Performance . . . That's SKINNER

VERTICAL "UNIVERSAL UNAFLOW" STEAM ENGINE

SKINNER

1. Steam-tight admission valve (at each end of cylinder). Double-seat. Permanently tight, regardless of variation in pressure and temperature.
2. Positive piston rod lock.
3. Pressure lubrication of all cam mechanism.
4. Dual camshafts for accurate timing and positive control of lead and cut-off. All cams, rollers and gears are hardened and ground to close tolerances. Rollers have line contact on cams.
5. Two-piece high-tensile iron piston. Eliminates troublesome core plugs.
6. Alloy iron cylinder, non-warping. Barrel-bored to compensate for expansion due to temperature gradient.
7. Steam packing (top) and bulkhead packing (bottom) with special bronze rings.
8. Forged alloy steel piston rod, ground to fine finish.
9. Permanent indicator reducing motion, with detent, for each cylinder. Permits taking indicator cards at any time without stopping engine.
10. Crosshead and pins, single-piece high-carbon steel forging.
11. Forged steel connecting rod, forked at upper end to reduce height, with heat-treated fitted bolts.
12. Box steel frame provides rigidity and total enclosure for cleanliness.
13. Rigid base, single-piece steel, double-wall construction.
14. Steam piping, and manifold (not shown), designed to permit expansion.
15. Steam-jacketed cylinder head.
16. Ample exhaust port area and manifold.
17. Steel cylinder jackets with polished steel bands and 85% magnesia cylinder lagging.
18. Permanent double ground joint—no gaskets.
19. Concentric rabbeting of guide, bottom head and cylinder to insure permanent alignment of unit assemblies.
20. Heat-treated alloy steel bolts, ground to size and accurately fitted to line-reamed holes.

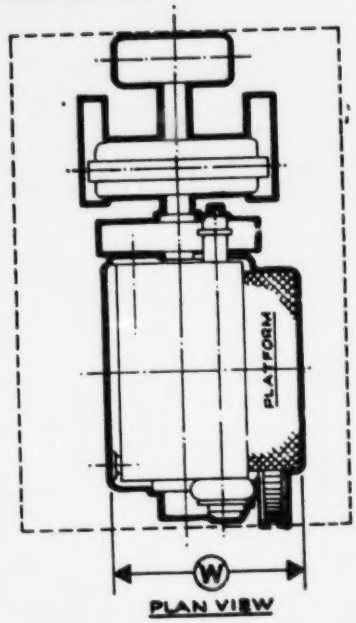


21. Crosshead shoe with tin-base babbitt top and bottom.
22. Bored crosshead guide, concentric with and parallel to the cylinder bore regardless of temperature changes.
23. Full force-feed lubrication through drilled crankshaft, connecting rod, crosshead pins and crosshead shoe.
24. Crank box, cast steel, lined with tin-base babbitt.
25. Bearing shell removable by rolling out.

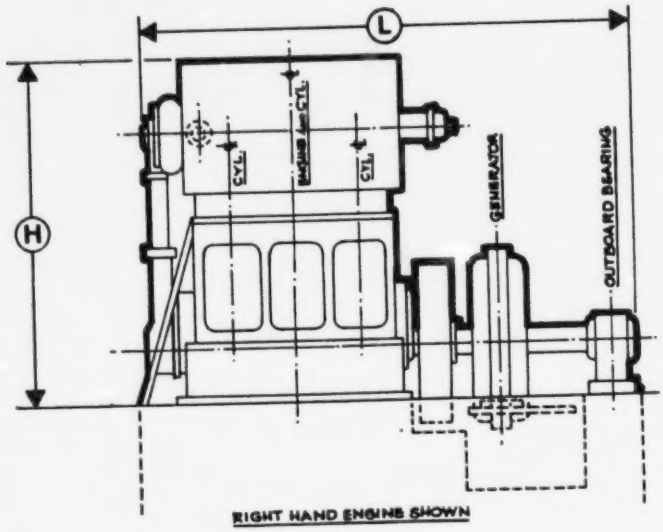
Progress Through Performance . . . That's SKINNER

SKINNER

STEAM ENGINE DESIGN DATA



PLAN VIEW



RIGHT HAND ENGINE SHOWN

ELEVATION VIEW

STEAM ENGINE TYPE			RV - FRAME (12" STROKE)		CV - FRAME (14" STROKE)		DV - FRAME (16" STROKE)	
NUMBER OF CYLINDERS			RV - 2	RV - 3	CV - 2	CV - 3	DV - 2	DV - 3
INDICATED HORSEPOWER		IHP	425	650	770	1150	980	1500
KILOWATT		KW	275	425	500	750	600	1000
ENGINE		RPM	400		360		327	
WEIGHT - ENGINE		LBS	29,000	40,000	44,000	50,000	49,000	62,000
WEIGHT - GENERATOR		LBS	6,200	8,600	9,500	11,500	11,000	15,000
WEIGHT - FLYWHEEL		LBS	7,000		7,000		10,000	7,000
DIMENSIONS INCHES and MILLIMETERS	WIDTH	Ⓦ	74/1880	76/1930	76/1930	84/2134	94/2388	
	LENGTH	Ⓛ	144/3658	176/4470	172/4369	204/5182	181/4597	211/5359
	HEIGHT	Ⓗ	116/2946		138/3505		151/3835	
	CTR. SHAFT to FLOOR LINE		18/457		24/610		24/610	
	PISTON ROD REMOVAL SPACE		30/762		33/838		35/889	
	FLYWHEEL SIZE	INCHES ONLY	70 x 10		70 x 10		70 x 15	70 x 10
	OUTBOARD BEARING	INCHES ONLY	7 x 13		7 x 13		8 x 15	10 x 18
STD. FOUNDATION, CU. FT.			700	840	1200	1350	1350	1500
DEPTH STD. FOUNDATION, FT. (MM)			5 (1524)		6 (1829)		6 (1829)	

REFER TO FACTORY FOR STEAM CONDITIONS and REQUIREMENTS OTHER THAN THAT LISTED IN ABOVE TABLE.

NOTE SINGLE and DUPLEX ENGINES OF THE PISTON VALVE TYPE AVAILABLE IN BRAKE HORSEPOWERS FROM 12 to 200 PRICES and DESCRIPTION UPON REQUEST

20", 24", 28", 30" and 36" STROKE ENGINES ARE AVAILABLE CHECK SKINNER ENGINE COMPANY

APPX. WATER RATE per KILOWATT HOUR
(DRY and SATURATED)
• TYPICAL EXAMPLES •

150 psig Inlet - 0# Back Press. - 31.7#/Kw.Hr.
150 psig Inlet - 12# Back Press. - 37.5#/Kw.Hr.
150 psig Inlet - 26" Vacuum - 21.7#/Kw.Hr.

300 psig Inlet - 0# Back Press. - 27.5#/Kw.Hr.
300 psig Inlet - 12# Back Press. - 30.0#/Kw.Hr.
300 psig Inlet - 26" Vacuum - 21.2#/Kw.Hr.

SEE BULLETIN STE-477 FOR STEAM ENGINE GENERATING SETS (ENERGEN - PAC) 4" TO 10" STROKE W/BRAKE HORSEPOWER TO 300.

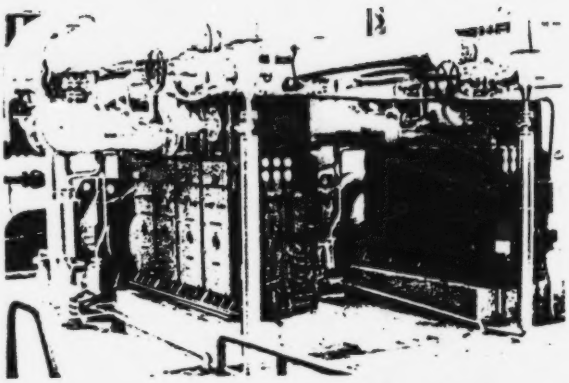
SKINNER ENGINE COMPANY POWER DIVISION
A SUBSIDIARY OF BANNER INDUSTRIES, INC.
P.O. Box 1149, Erie, Pennsylvania 16512
Phone: 814-454-7103 • Telex: 91-4481

PRINTED IN U.S.A.

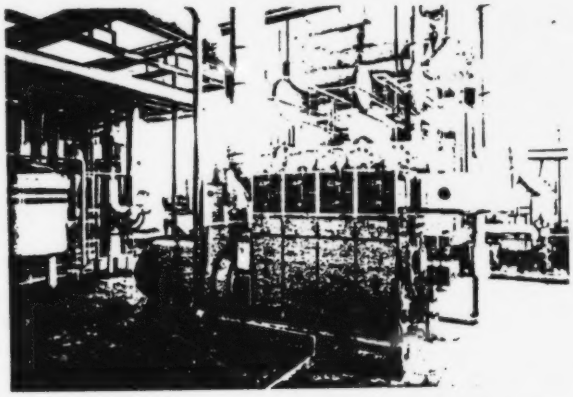
SPILLING
ENERGIE

SPILLING POWER PLANTS

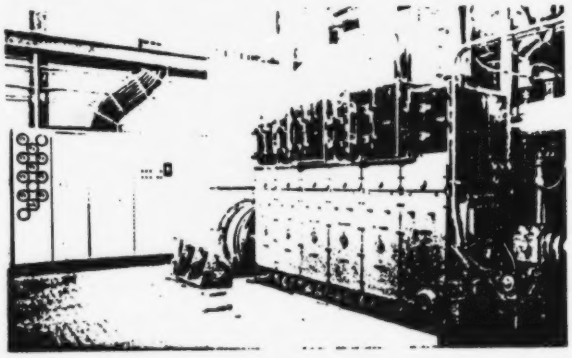
SPILLINGMOTOR
BAUKASTENMOTOR



Woodworking factory in Africa, power plant with 2 SPILLING steam motor sets each of 800 KVA, wood fuel. Regulation according to power demand.



SPILLING steam power plant with 800 KVA set and waste heat boiler behind glass trough in a German glass factory. Regulation according to waste heat available and to bleeding steam required.



Solar power plant in Almeria, Spain, with 600 KW SPILLING set, fully automatic program-controlled operation: 100 bar/500°C/ 3100 kg/hr one-tube steam generator.

OUR PROGRAM

Supply of individual engines or generating sets up to turn key plants ready for operation.

STEAM MOTORS
REFRIGERANT VAPOR MOTORS (in ORC plants)
GAS-EXPANSION MOTORS

for driving generators (3-phase current or direct current) or working machines such as pumps, compressors, blowers, screw presses, paper-making machines, transmissions, frame saws, extruders etc.

20 to 3000 KW, 500 to 1500 RPM, 5 to 150 bar,
isolated or parallel operation,
constant speed or infinitely variable speed regulation in the range up to 1:10

STEAM POWER PLANTS

for oil, gas or coal as fuels, but also for fuels of waste materials (plants built for using scrap wood, peanut shells, coffee bean shells, coconut waste, karite seed husks, cotton seed husks, cashew nut shells, rice husks etc.).

STEAM and REFRIGERANT VAPOR POWER PLANTS

for utilizing waste heat from exhaust gases with waste heat boilers or from vapors and liquids with heat exchangers down to final temperatures of about 70 °C.

GAS-EXPANSION MOTOR plants

as pressure reducing stations using excess-pressure energy and installed on the input side of natural gas consumers or for other gases in industrial processing plants.

In addition high temperature heat pumps as
STEAM COMPRESSORS

for the effective steam pressure range up to 150 bar in single and multi-stage construction, with heat transmission via intermediate radiator, mostly with speed regulation, driven by electric motors, STEAM MOTORS, GAS-EXPANSION MOTORS or also by internal combustion motors.

**OPTIMUM PRIMARY ENERGY UTILIZATION
WITH EXACT TAYLOR MADE POWER PLANTS
AND HIGH TEMPERATURE HEAT PUMPS.**

SPILLING
ENERGIE

SPILLINGWERK HAMBURG GMBH
Werftstraße 5
D-2000 Hamburg 11

SPILLINGMOTOR
BAUKASTENMOTOR

OUR EXPERIENCE

SPILLING MODULAR SYSTEM MOTORS are robust prime movers for single and multi-shift operation.

Power plants planned, erected and tended by us are working in some cases already for many years in works of all kinds and in most countries of Europe, Africa, South and Central America and of Asia.

Our experience with the most varied personal, technical and climatic working conditions is of great benefit to all projects being newly planned.

In almost all steam power plants the SPILLING MOTORS are operated by the same personnel that is responsible for the boilers. This applies just as much to the simplest plants turned on and off by hand as to those that are automatically regulated or are operated with a full automatic system together with boiler plants without constant supervision.

Added to our experience with stationary plants in closed buildings or only simply roofed over or in the open there is further experience with some hundreds of SPILLING MOTORS on sea-going and river vessels.

OUR CUSTOMERS

are FACTORIES from all fields and branches of industry (wood, textiles, paper, ceramics, glass, leather, chemicals, refineries, foodstuffs, breweries, dairies, preserved food factories, oil mills, sugar factories, slaughter houses etc.)

and MUNICIPALITIES for heating power stations, hospitals, bathing establishments etc.,

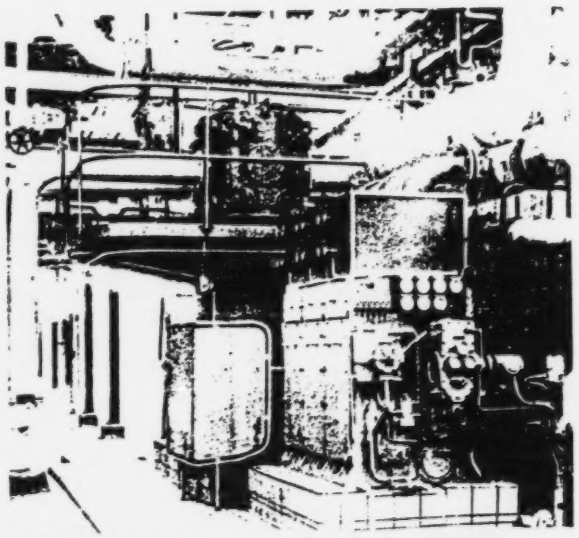
and SHIPYARDS, MACHINE MANUFACTURERS, EXPORTERS.

OUR ADVANTAGES

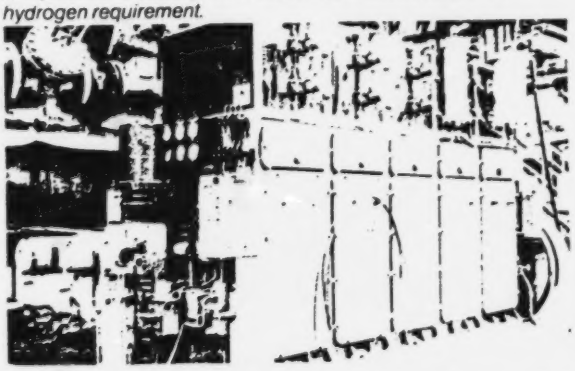
result from the construction of our machines, which are built up to standard parts and can be maintained and repaired by the factory's own staff, which is of the greatest importance, especially for plants in overseas countries.

We can therefore – if necessary – guarantee extremely short delivery periods.

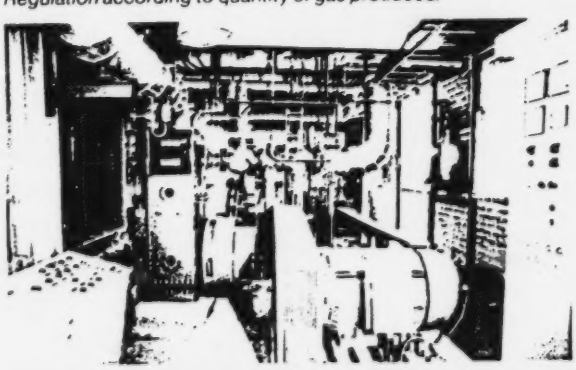
Spare parts are available ex stock for replacement. This applies also to replacement 3-phase current synchronous generators of the series running at 1000 RPM.



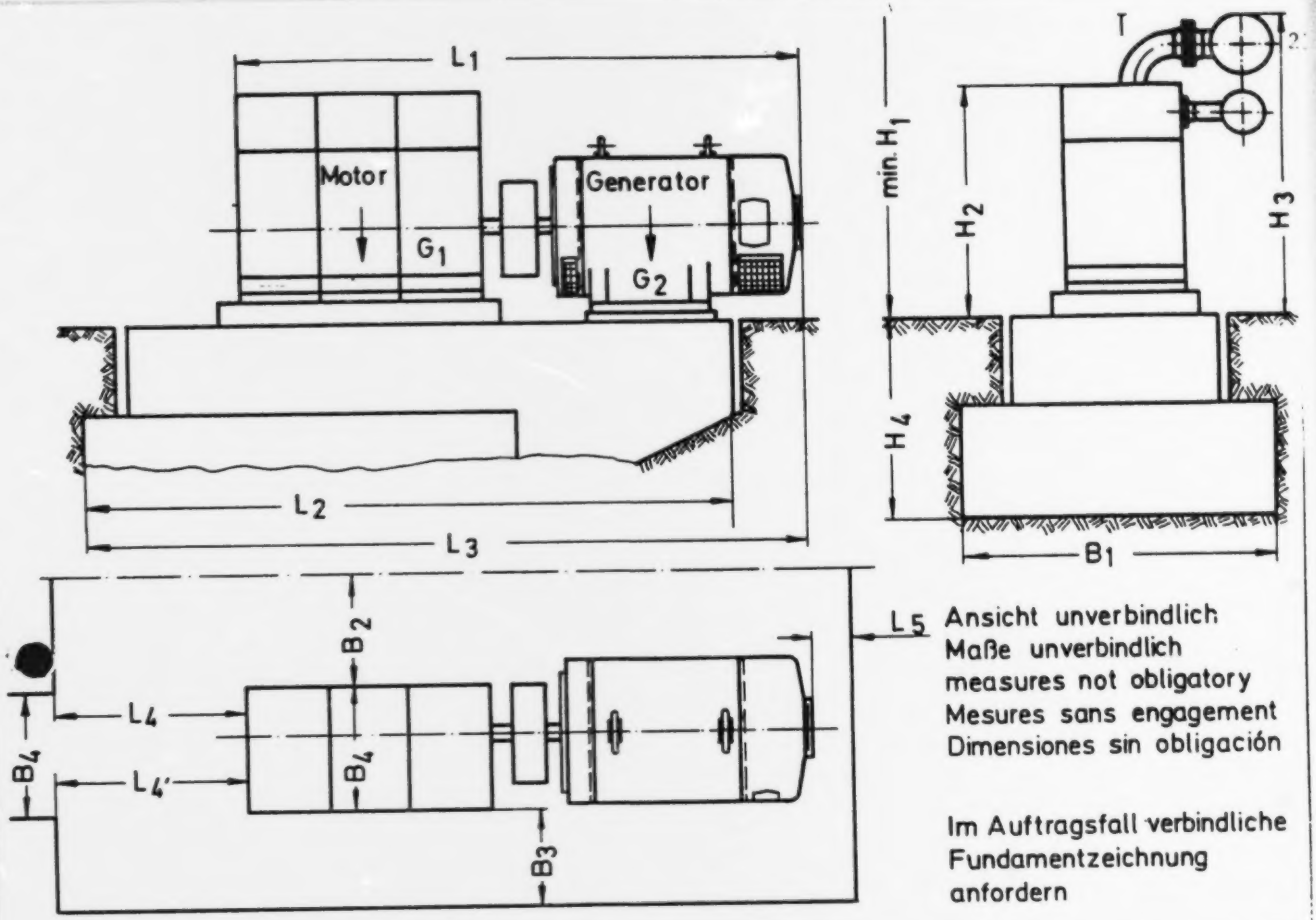
Speed regulated SPILLING MOTOR for driving hydrogen compressor in refinery in Holland. Regulation dependent on hydrogen requirement.



3-cylinder SPILLING GAS-EXPANSION MOTOR built in one unit with 2-cylinder, 2-stage STEAM COMPRESSOR in process operations of a gas production plant in Denmark. Regulation according to quantity of gas produced.



150 KW SPILLING ORC-power plant utilizing 260°C exhaust gas heat in a German chemical works. Regulation according to waste heat available.



Ansicht unverbindlich
Maße unverbindlich
measures not obligatory
Mesures sans engagement
Dimensiones sin obligación

Im Auftragsfall verbindliche Fundamentzeichnung anfordern

Motor Zyl.	1/min	PSe	t Mot.	t Gen.	P1	m L1	L2	L3	L4	L5	B1	B2	B3	B4	H1	H2	H3	H4	L4'	
1	1500	40/50	0.5	0.30		1.4	1.6	1.8											1.0	
2		80/100	0.85	0.50		1.8	2.0	2.2												
3		120/150	1.2	0.70		2.2	2.4	2.6		0.5	1.5			0.42	1.9	1.1	1.5	1.5	1.1	Type 7
4		160/200	1.5	0.80		2.6	2.8	3.0												
5		200/250	1.9	0.95		2.8	3.2	3.4											1.33	
1	750	160/200	2.0	1.0		2.4	2.8	3.0											1.0	
2		320/400	3.5	1.6		3.0	3.4	3.6			2.8								1.2	
3		480/600	5.0	2.0		3.5	4.0	4.2											1.6	
4		640/800	6.5	2.4		4.2	4.5	4.7	1.0	0.8	2.6	1.0	0.7						2.1	
5		800/1000	8.0	3.0		4.9	5.1	5.4											2.5	Type 14
6		960/1200	9.5	3.5	1	5.4	5.6	5.9						0.72	2.8	1.9	2.4	2.0	3.0	
1	1000 900	200/300	2.0	1.0		2.5	2.9	3.1			3.5								1.0	
2		400/600	3.5	1.6		3.1	3.5	3.7											1.2	
3		600/900	5.0	2.0		3.6	4.0	4.2											1.6	
4		800/1200	6.5	2.4		4.2	4.5	4.7			3.0								2.1	
5		1000/1500	8.0	3.0		4.7	5.1	5.3											2.5	
6		1200/1800	9.5	3.5		5.2	5.6	5.8											3.0	Type 12
8		1400/2100	12.5	4.5		6.2	6.6	6.8											4.0	
10		1700/2500	15.5	5.5		7.2	7.6	7.8											5.0	

Für diese Zeichnung behalten wir uns alle Rechte vor

81		Sei	Dampf steam vapeur vapor SPILLING- Aggregat auf Betonfundament concrete foundation massif en beton fundamento de beton
13.9.79			Ma 355-3
Ersatz für	Ersetzt durch		Spilling

APPENDIX III

EQUIPMENT AND ROAD COSTS

APPENDIX III

EQUIPMENT AND ROAD COSTS

		COST PER DAY
A.	EQUIPMENT COSTS	
	1. Massey Ferguson 245 Tractor With Rear Forks ($16,185)	
	Depreciation over 10,000 hours	$ 12.96
	Fuel and lubricants, 6.82 litres per hour	43.65
	Maintenance and repairs, 60% of depreciation	7.78
	Tires (3,000 hours)	4.26
	Total cost per day	$ 68.65
	2. Wagon With Superstructure ($3,000)	
	Depreciation over 10,000 hours	$ 2.40
	Maintenance and repairs, 60% of depreciation	1.44
	Tires (3,000 hours)	2.67
	Total cost per day	$ 6.51
	3. Loading Unit, Case 580D Front-End Loader With Backhoe (Unit Price - $40,000)	
	Depreciation over 10,000 hours	$ 32.00
	Fuel and lubricants, 10.46 litres per hour	66.94
	Maintenance and repairs, 60% of depreciation	19.20
	Tires (3,000 hours), 1.67 x 8	13.36
	Total cost per day	$ 131.50
B.	ROAD COSTS - KWADACHA MAIN HAUL ROAD ($50,000)	
	Volume of deciduous developed	21,889 m3
	Volume on right-of-way	2,039
	Volume on skid trails, 4.8 percent of total volume in type	6,897
	Total	30,825 m3
	Write-off rate per m3 = 50,000 divided by 30,825	$ 1.62
	Write-off rate per cord =	$ 3.69

APPENDIX IV

UNIT COSTS DELIVERED TO THE PLANT SITE

APPENDIX IV

UNIT COSTS DELIVERED TO THE PLANT SITE

ITEM	COSTS TOTAL PER DAY	PER CORD	PER m3
A. THE RECOMMENDED PROGRAM - LABOUR INTENSIVE - 20 CORDS PER DAY			
Equipment			
Tractor (2)	$ 137.30	$ 6.87	
Wagon (2)	13.02	.65	
Labour (12 men)	780.00	39.00	
Power saws (8)	120.00	6.00	
Road write-off	73.80	3.69	
Total	$1,124.12	$56.21	$24.73
B. THE ALTERNATIVE PROGRAM - LOADER INTRODUCED DAILY DELIVERIES TO PLANT DOUBLED			
Equipment			
Tractor (2)	$ 137.30	$ 3.43	
Wagon (2)	13.02	.33	
Loader (1)	131.50	3.29	
Labour (11 men)	715.00	30.87	
Power saws (8)	120.00	6.00	
Road write-off	147.60	3.69	
Total	$1,264.42	$47.61	$20.95
C. THE ALTERNATIVE PROGRAM - LOADER INTRODUCED DAILY DELIVERIES TO PLANT 1.5 TIMES			
Equipment			
Tractor (2)	$ 137.30	$ 4.58	
Wagon (2)	13.02	.43	
Loader (1)	131.50	4.38	
Labour (11 men)	715.00	32.50	
Power saws (8)	120.00	6.00	
Road write-off	110.70	3.69	
Total	$1,227.52	$51.58	$22.69

APPENDIX V

EXPLANATION OF TYPE CODING AND SPECIES ABBREVIATIONS

[illegible] ...ages ... age class, height class ... or secondary ... [illegible] ... species ... [illegible] ... species comprising 10 - 19 % of ... stands are based on number of stems.

STOCKING

Apply to	Limits - No. of trees per acre 11.1" + d.b.h.
all immature	N.A.
mature	31+
mature	1-30

Scattered veterans a.g. + P Vets
Secondary volume a.g. + P Vols
Secondary immature a.g. + P Imms.

ST MAP LABELS

...ume. Age 121 - 140 years, height 96 - 125 feet.

...: Stocking zero means type is immature. Medium site
... Secondary for volume present in [illegible] quantity

...0. Scattered FC Veterans occur

...PI. Age 141 - 250 years, height 1-35 feet, stocking

...: ...ow forest site

...d.

...maple.

...ame.

...ID

...ding
...ared

...ndow

...S ABBREVIATIONS